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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1428

Washington, D. C. ▼ October, 1926

THE CADELLE

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ORIGIN AND SYNONYMY

The cadelle (*Tenebroides mauritanicus* Linné) is an important pest of grains and of grain products such as flours and milled breakfast foods. It belongs to an extensive family of beetles, nearly all of which are inhabitants of the New World. For this reason it has been thought by some to be native to America. The fact, however, that it alone of the genus Tenebroides has the habit of feeding upon grain or grain products—a habit that must have been acquired centuries ago—leads one to suspect that it may possibly be a native of the Old World, where the custom of storing grain for food was first established. Early English writers thought it had been introduced to England from Africa. At the time of its description in 1758 it had undoubtedly been carried by commerce to nearly all parts of the civilized world.

In 1758 it was first described by Linné (*20, p. 417*),[1] who gave it the name of *Tenebrio mauritanicus* and classified it with the meal worm, *Tenebrio molitor*, which he described at the same time. Thirty-two years later, in 1790, Olivier (*23, p. 242*) published a short account of this insect and proposed for it the generic name of Trogossite (from the Greek words τρωγω, to eat, and σῖτος, grain). For many years thereafter it was known as *Trogosita mauritanica* and until recently the family of beetles to which it belongs was known as the Trogositidae.[2]

[1] Numbers in italic in parentheses refer to "Literature cited," p. 39.

[2] The family was later known under the name of Temnochilidae and is now called the Ostomidae.

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In 1783, however, a few years previous to the publication by Olivier, Piller and Mitterpacher (*26, p. 87*) described a beetle under the name *Tenebroides complanatus* and characterized their genus Tenebroides on this species. A rather poor illustration accompanied the description, but it has been generally recognized by scientists as the *mauritanicus* of Linné. Hence the name Trogosita gave place to that of Tenebroides, under which the insect is now known.

The conspicuous size and habits of this insect attracted the attention of many scientists, and during the eighteenth century it was described several times under different names. The synonymy of *Tenebroides mauritanicus* (Linné) as given by Léveillé (*19, p. 438–439*) is as follows:

mauritanicus Lin. Syst. Nat. ed. X. I. p. 417 (1758).—J. Duv. Gen. II. t. 42. f. 208.—[*Larva*] Cf. Rupertsberger, Biol. Käf. Eur. p. 130 ..... *cosmopolit.*
bucephalus Herbst, Arch. p. 141. t. 29. f. 16 (1784).
caraboides Fabr. Syst. Ent. p. 256 (1775).—Sturm. Ins. II. p. 242. t. 48 ..... *Europa.*
complanatus Piller, It. Poseg. p. 87. t. 9. f. 9 (1783).
dubius Scriba, Journ. p. 42. 6 (1790) ..... *Germania.*
fuscus Goeze, Ent. Beytr. 1. p. 125 (1777).—Geoffr. (*Platycerus no. 5*). Hist. Ins. I. p. 64.—Preyssl. Verz. böhm. Ins. I. p. 6. t. 1. f. 1 (1790).
piceus Schaller, Act. Hall. I. p. 319 (1783) ..... *America.*
planus Quensel, Diss. inaug. p. 19 (1790) ..... *Barbaria.*
striatus Fourcroy, Ent. par. I. p. 3 (1785) ..... *Gallia.*
var. *nitidus* Horn, loc. cit. [Proc. Ac. Phil. 1862] p. 83.—Cf. Reitt. loc. cit. [Verh. nat. Ver. Brünn.] p. 79 (16) ..... *Philadelphia.*

COMMON NAMES

Tenebroides mauritanicus has few common names, "cadelle" appearing to be, on the whole, most generally satisfactory. This is the name by which the larva was popularly known to the French, according to Olivier (*23, p. 242*) in his paper published in 1790. Taschenberg (*32, p. 16–18*), in 1879, called the cadelle the "bread beetle" because he had found it in bread. In like manner Johnson (*14*), in 1896, proposed to call the cadelle "the bolting cloth beetle" because it eats holes in bolting cloth in flour-mill machinery. Since the names "bread beetle" and "bolting cloth beetle" do not embrace the varied activities of the insect, the writers have selected the more generally accepted name, cadelle.

ECONOMIC HISTORY

References to the destructiveness of the cadelle to grain began to appear shortly after it was described as a new species by Linné (*20*) in 1758. Dorthes (*8*), in 1787, wrote of it as destructive to wheat and Olivier (*23, p. 242*), in 1790, stated that the insect was common throughout France, attacking wheat in granaries. Some 20 years later, in 1812, Kirkup (*17*) gave the first real contribution to our knowledge of the life history of the cadelle by recording observations on a specimen which was known to have remained as a larva with a Spanish almond meat for 15 months before transforming to the adult, and to have lived as an adult an additional year and nine months. Kirkup stated that the cadelle was not common in England at that time but was occasionally found on board ships. In

1802 Parmentier (*25*, *p. 355*) referred to the damage caused to stored wheat in France, and in 1841 (Harris (*11*), writing in America, stated that although the cadelle caused considerable damage in Europe, he was "not aware that they have been found in our own garners," probably meaning by this, in the Northeastern States.

In 1860 Curtis (*4*, *p. 332–333*) stated that the pest occurred over the greater part of Europe, and that it attacked not only wheat and corn, but bread and nuts, and even dead trees. He records an interesting instance where the cadelle larvæ became extablished in the rotten floor of a malt house in Cambridge, England. Curtis observed that the damage done to grain by the cadelle is partially offset by its carnivorous attack upon the wolf moth, *Tinea granella* L., also a grain pest. Glover (*10*, *p. 66*), in 1871, recommended kiln drying of infested grain to destroy the cadelle. LeBaron (*18*, *p. 64*), in 1874, and Thomas (*33*, *p. 93*), in 1878, stated as their belief that the cadelle was chiefly carnivorous and fed upon species of Calandra and Tinea infesting grain. As previously stated, Taschenberg (*32*, *p. 16–18*), in 1879, wrote of the insect in Germany and named the pest the "bread beetle," because he found it infesting bread and bake shops in his country. Riley and Howard (*28*), in 1888, recorded finding a cadelle pupa in a bottle of milk. In the following year Webster (*34*) discovered specimens that had bored through a cork-stoppered bottle and had then burrowed through powdered white hellebore; and Lugger (*21*), in 1890, gives an interesting account of the pupal chambers made by larvæ in a book (*Pl. VII*, *C*). Forbes (*9*, *p. xi–xii*), in 1890, mentioned that in Illinois the cadelle larvæ were found boring holes in the sides of a granary for the apparent purpose of transformation.

Plumacher (*27*), in 1891, recorded the presence of the cadelle in corn in Venezuela, and three years later Riley (*29*, *p. 219*) stated that cereals grown in South America and Central America were found, when exhibited at the Columbian Exposition, to be infested by the cadelle. The same year (*1894*) Riley and Howard (*30*) recorded the accidental presence of the cadelle in sugar. In 1895, Chittenden (*1*, *p. 290–291*) gave a brief account of the cadelle, called attention again to the fact that it often damages many more kernels of grain than it consumes, listed foods eaten by the insect, and established the fact that the cadelle is both predacious and grain-eating. In 1896 (*2*, *p. 122–124*), in a chapter on insects affecting cereals and other dry vegetable foods, in a bulletin on the principal household insects of the United States, he stated his belief that the cadelle is of American origin and has one generation annually. He records the larvæ in powdered sugar and suspects that their presence there is due to adulteration of the sugar with flour.

Johnson (*13*, *14*, *15*), writing in the American Miller in 1895, 1896, and 1898, gave to the cadelle the name "bolting cloth beetle" because it often cuts the silk bolting cloth in flour-mill machinery. He recorded severe damage by the cadelle to 2,000 bushels of wheat which were found in 1894, on one farm in Illinois, to be swarming with cadelle larvæ. In 1899 he recorded (*16*, *p. 67*) that cadelle larvæ bored through the parchment coverings of jam and jelly jars arriving at Baltimore from England, and that the larvæ fed upon the sweets.

Davis (*5, p. 21*), in 1896, recorded the insect present in beans. Ormerod (*24, p. 56–59*), in 1900, referred to the presence of the cadelle in bakers' shops, granaries, etc., in England, and expressed the opinion that because of their predacious habit the cadelles, when present in flour or meal, on which so far as she was aware neither the beetle nor its maggot fed, were doing more good than harm; as grain pests, however, she stated that the case was different. R. I. Smith (*31, p. 11–12*), writing from North Carolina in 1909, after a study of the grain-pest problem there, came to the conclusion that any beneficial result following the attack of the cadelle upon other grain pests was greatly counterbalanced by the insect's direct attack upon the grain.

Dean (*6, p. 205–207, figs. 18–19*), in 1913, after a study of flour infestation both in America and Europe, established the seriousness of the cadelle infestations in flour and came to the conclusion that the cadelle is one of the most serious of mill pests. Herrick (*12, p. 232–236*), in 1914, published original data by Slingerland indicating an incubation period of about 10 days for the egg, and a life cycle of about one year's duration.

Zvierezomb-Zubovsky (*35*) in 1919, McColloch (*22*) in 1922, and Cotton (*3*) in 1923, published original biological data that greatly increased our knowledge of the cadelle. Zvierezomb-Zubovsky found that eggs are laid in batches from 18 to 27 in number and hatch in from 7 to 24 days, that the larval stage lasts from 98 to 115 days during which the larva molts five times, and that the pupal stage lasts from 8 to 30 days. Although his work indicated but one generation a year, McColloch found the larval stage to extend over such long periods (from 628 to 1,248 days) that he questioned whether or not the cadelle life cycle might not be much longer than thought by previous writers. Cotton, however, in his paper preliminary to the present paper, gave convincing data on all stages that left no doubt that the cadelle may have two generations each year.

DISTRIBUTION

The cadelle is cosmopolitan in distribution, being found in all parts of the world where grain and grain products are stored. It has been found in all flour mills and manufacturing plants, warehouses, elevators, and farmers' grain bins examined by the writers, no matter whether these were on the Atlantic coast or the Pacific coast, in the North or South. It is easily distributed in grain and grain products and hence is carried with the greatest ease along trade channels. It was abundant in wheat arriving at American ports during the war from Australia, and in rice, peanuts, and other stored products from the Dutch East Indies. Cargoes of corn arriving at New York from South American ports always carry the cadelle. Nut meats arriving in the United States from the Mediterranean regions often are infested. The dunnage of ships frequently carries thousands of cadelles from country to country, and in America, at least, the universal use of breakfast foods carries specimens to nearly every home at some time or other.

NATURE OF INJURY

The association of the cadelle with other grain pests which are more in evidence often aids in obscuring its extremely varied injury. The cadelle larva and adult are both rather restless and do not feed continuously in one place. Both can gnaw holes through sacks, parchments, cardboard (fig. 1), waxed and other papers (fig. 2), and even wooden boards (figs. 3, 6, 7, and 8), and whether they penetrate such substances directly in search of food, or accidentally in making suitable chambers for transformation (fig. 11), the result is the same—the exposure of susceptible foods to hordes of associated pests that might not otherwise have been able to gain access to the food supply.

All who have observed the feeding of the cadelle have noted its preference for the germ of the grains upon which it feeds, and know that the larva and adult may travel from seed to seed and remove the germ from many more seeds than could possibly be completely devoured. The larva, however, is more likely to become embedded in the larger seeds, such as corn, and, half in the seed itself and half in the burrowed-out cob (fig. 4, C), feed upon a seed until little is left except the outer portion. Even small kernels such as those of wheat may be completely devoured except for the outer coverings. On a Maryland farm in 1921 the writers observed cadelle larvæ so abundant in 800 bushels of wheat that the kernels appeared to move, and larvæ could be gathered by the peck. They have also seen larvæ removed by the pailful from rice which had been stored for some time in New York warehouses, and tremendous numbers from flour which was being reconditioned in New Orleans warehouses and wholesale grocery establishments after a season's storage. Dean (*6*, *pp. 205–207*) has recorded finding 1,460 and 1,001 larvæ, respectively, in two 140-pound sacks of flour.

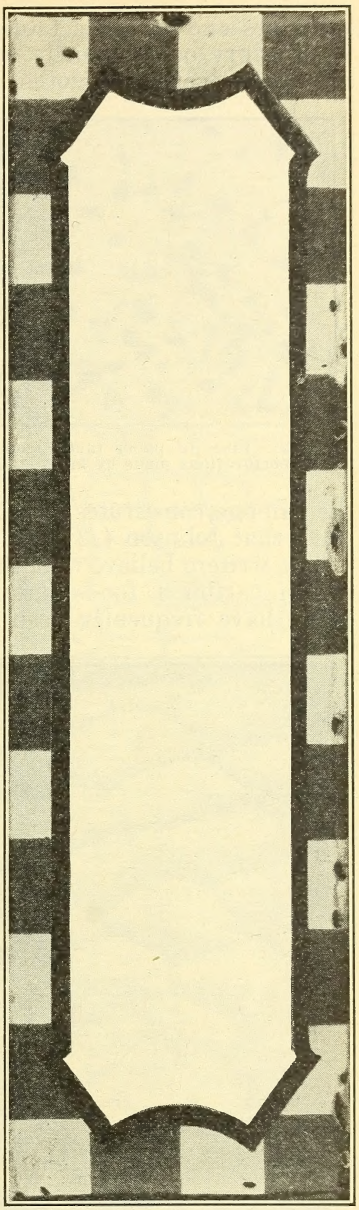

FIG. 1.—Side view of carton of flour showing holes cut in the cardboard by larvæ and adults of the cadelle. Such holes open cartons to the attack of all small grain pests

In flour mills injury by the cadelle is clearly evident from the holes eaten by both larvæ and adults in the silk cloth used in the bolting

machines and in other fabrics from the sifters (fig. 5). Although such injury occurs chiefly while the machinery is at rest, the time required to patch the cloths, or the impaired efficiency resulting from

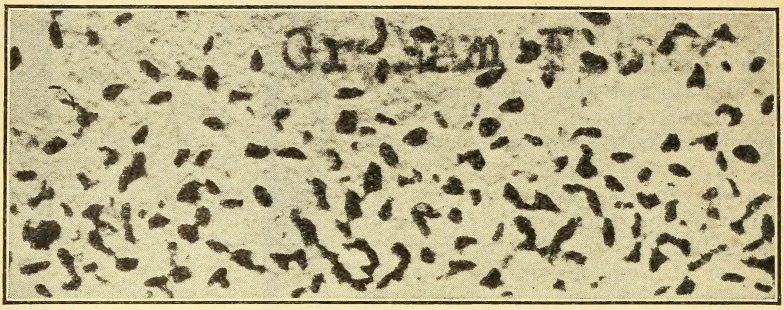

FIG. 2.—Piece of paper taken from top of inside of carton of graham flour. Note perforations made by larvæ and adults of cadelle developing within the flour

the damage, constitutes a real loss. This type of injury is so severe at times that Johnson (*14*) named the cadelle the "bolting cloth beetle."

The writers believe that the losses brought about by cadelle activity in cartoned foods has been greatly underestimated. Cadelle larvæ have frequently been found in flours, breakfast foods, dried

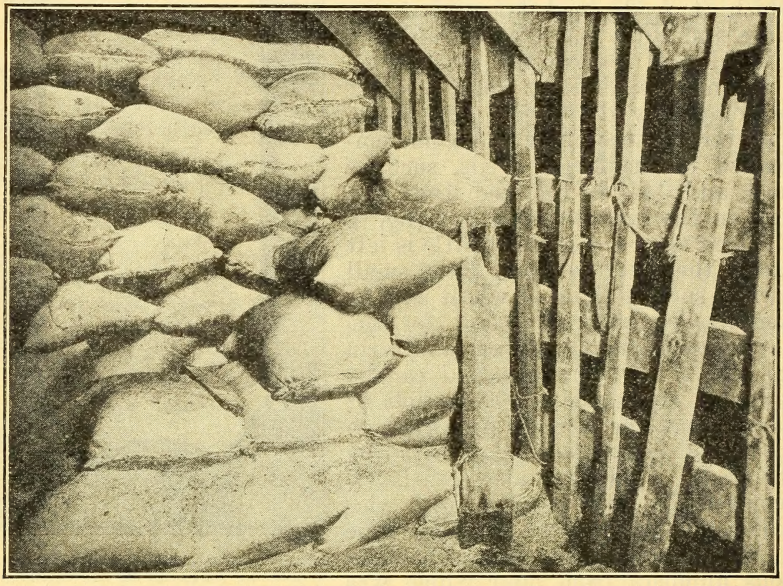

FIG. 3.—View in hold of grain ship, showing dunnage used to keep sacks of wheat from touching steel sides of ship. Such dunnage used over and over again becomes well infested by the cadelle, and with the assistance of the cadelle becomes also the hiding place for many associated grain pests

fruits, pearl barley, etc., placed on the market in packaged form. A cadelle larva seldom pupates within such a package, but in seeking seclusion for transformation it eats a hole in the carton to effect its escape (fig. 1). It thus opens the carton to all the other chief pests

of cartoned goods and indirectly brings about a loss that is seldom charged to the cadelle itself.

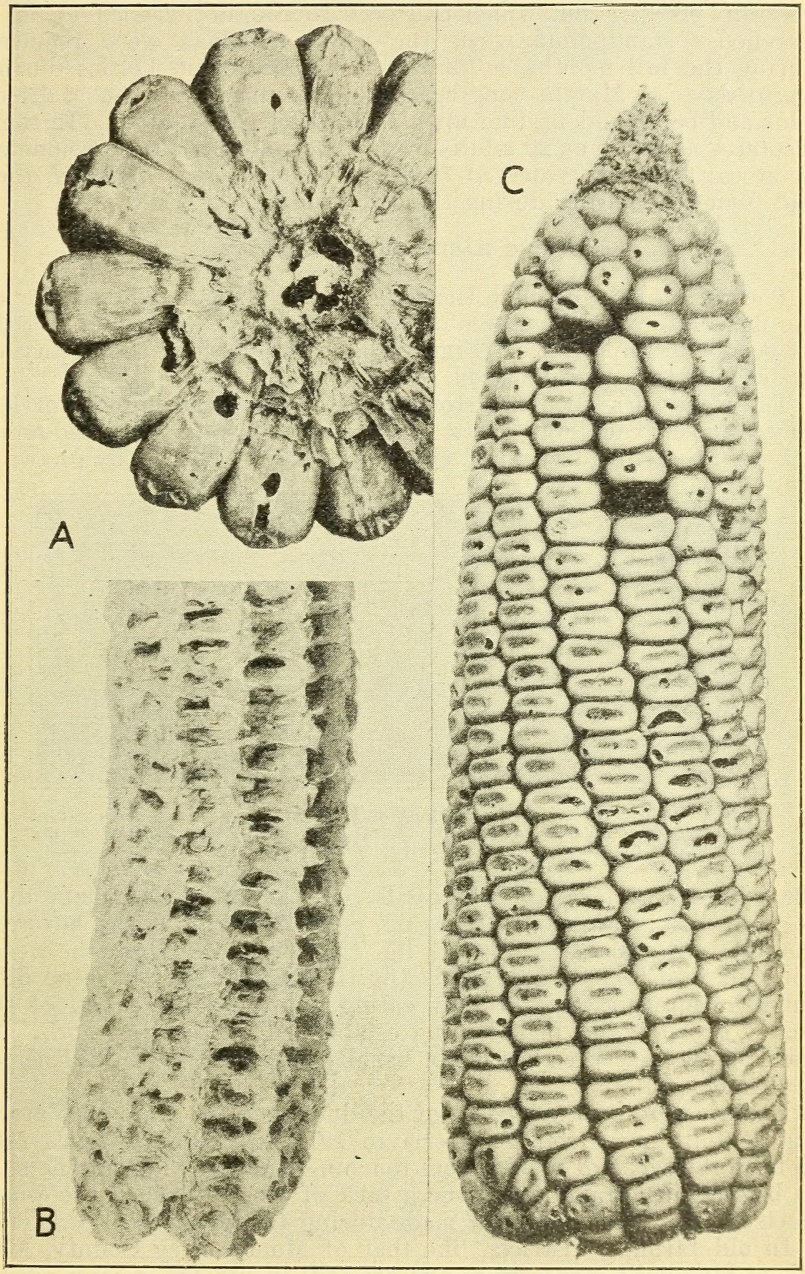

FIG. 4.—A, Burrows of cadelle larvæ in pith of corn cob; B, the dark spots in corn cob indicate burrows of cadelle larvæ which are often found partially concealed in such spots with the remainder of their bodies filling the hollowed-out corn kernel; C, kernels showing evidence of infestation by *Sitotroga cerealella* and cadelle. The large siltlike openings are evidence of cadelle feeding

In warehouses used for the storage of miscellaneous products the cadelle may cause much annoyance at times. Thus, in a warehouse in Baltimore which had been used the summer before for the storage of grain products but which had been thoroughly cleaned (from a warehouse standpoint) when the grain products were removed during the fall months, adult cadelles appeared in hordes during warm days in March, congregating in numbers between sacks of flour and beans and feeding upon carload lots of potatoes. In some instances as many as 20 adults could be counted about abrasions on potatoes; these had emerged from the wooden floor, in which they had been hibernating during the cold months.

BORING HABITS OF THE CADELLE

The boring habit of both the cadelle larva and the adult is one of the most interesting features of its activities, and enhances greatly its economic importance. Figures 6, 7, and 8 show the ability of the cadelle to bore into wood.

The woodwork about all storage places for grain is more or less penetrated by cadelle burrows. If the wood is very hard, the larvæ may be forced to form pupal chambers between boards, by gnawing

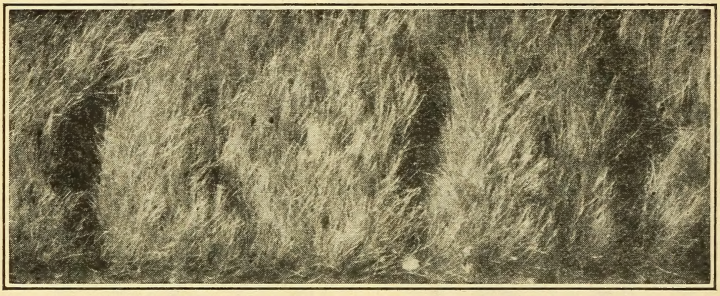

FIG. 5.—Fabric from shifting machine of flour mill showing channels cut in pile by cadelle larvæ and adults. These cuts reduce the efficiency of the machinery and necessitate replacement of fabrics

the adjacent surfaces of the boards. In the case of ordinary dunnage used in grain ships (fig. 3; fig. 6, B, D, E; fig. 8, B), however, the wood of granaries (fig. 6, C; fig. 7, B; fig. 8, A, B), or the woodwork of feed bins in flour mills (fig. 7, A), etc., they have no difficulty in entering the wood by eating out the softer wood of the yearly growths and in becoming established by the thousands. In such places their presence is not usually suspected by the farmer or grain dealer.

Examination by the writers of the dunnage of a grain ship arriving at Baltimore from Australia in 1918 showed the boards used to keep the sacks of wheat from touching the steel sides of the ship to be well perforated wherever a sack of wheat touched the wood. Such borings were of course made during the voyage.

In old farming districts, like that of Montgomery County, Md., where bins built many years ago are still in use for storing wheat, the burrows may be so numerous and may have been so lengthened by the borings of generation after generation of cadelle larvæ and adults that the wood has become well honeycombed. Observe in

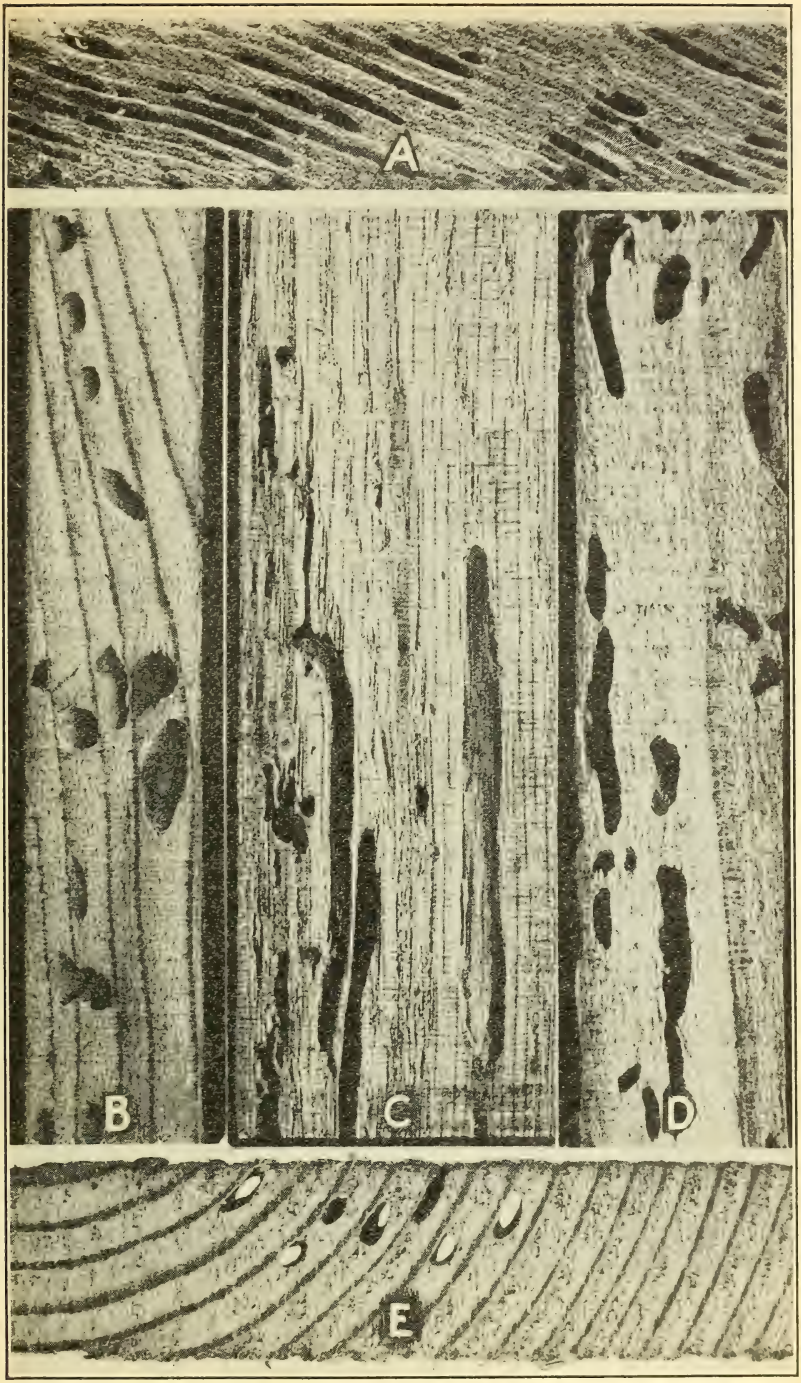

FIG. 6.—Cadelle burrows in wood: B, D, and E, Sections of 1-inch soft wood; A, excavations made in oak board used as cover for elevator boot in flour mill; C, section of oak timber from granary exposing three long larval burrows

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Figures 7, B, and 8, A, longitudinal and cross sections of a 3 by 3 inch oak timber honeycombed by cadelle larvæ. Individual larval

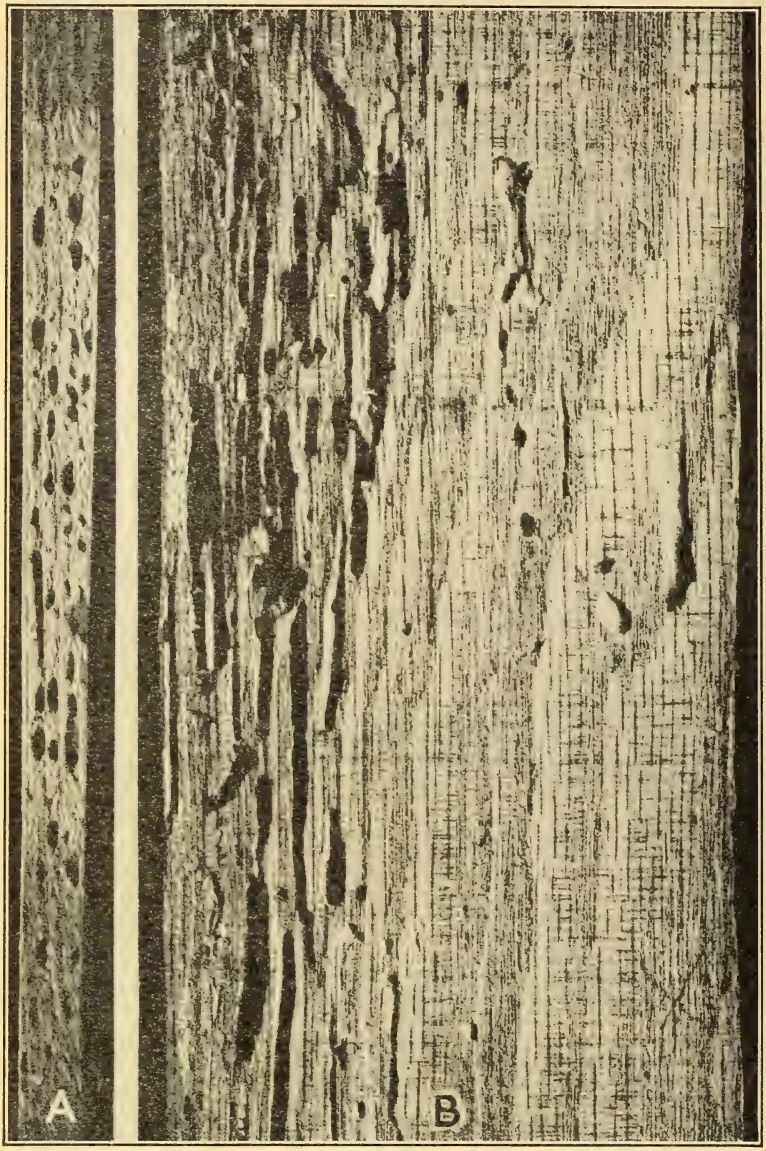

FIG. 7.—Cadelle burrows in wood: A, Quarter-inch strip of soft wood riddled by larvæ taken from bran bin of flour mill; B, longitudinal section of 3-inch oak timber used as rafter in roof of 100-year-old wheat granary on Maryland farm (for cross section see fig. 8, A)

channels may be as long as 2¼ inches. One-inch boards of pine are easily perforated. Figure 6, A, shows the excavations made in a hardwood board used as top to a flour elevator in a mill. In one

yellow-pine board 42 by 4 by 1 inch taken from a farmer's bin near Washington, D. C., there were estimated to be 6,160 holes through which larvæ or adults had entered or left the board. The flooring

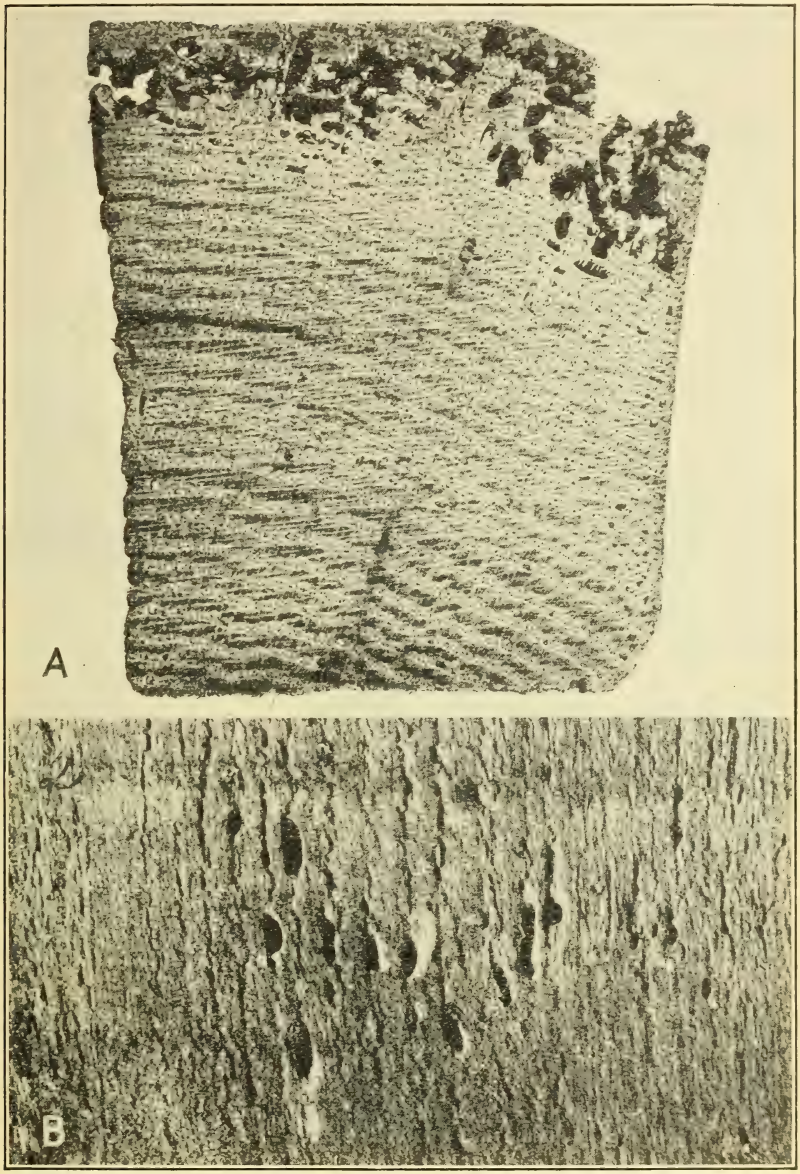

FIG. 8.—Cadelle burrows in wood: A, Cross section of oak timber used as rafter of wheat granary on Maryland farm for over 100 years, showing the exposed surface honeycombed by cadelle larvæ; B, external view of board from side walls of granary, showing entry and exit holes of cadelle larvæ and adults

of another bin which had been in place for many years, and upon which wheat had been placed each year, was found so riddled as to be unsafe. In several old bins the writers have observed cadelle

larvæ burrowing not only into the woodwork of floors and sides of the bins but into the rafters, beneath shingles, and wherever the

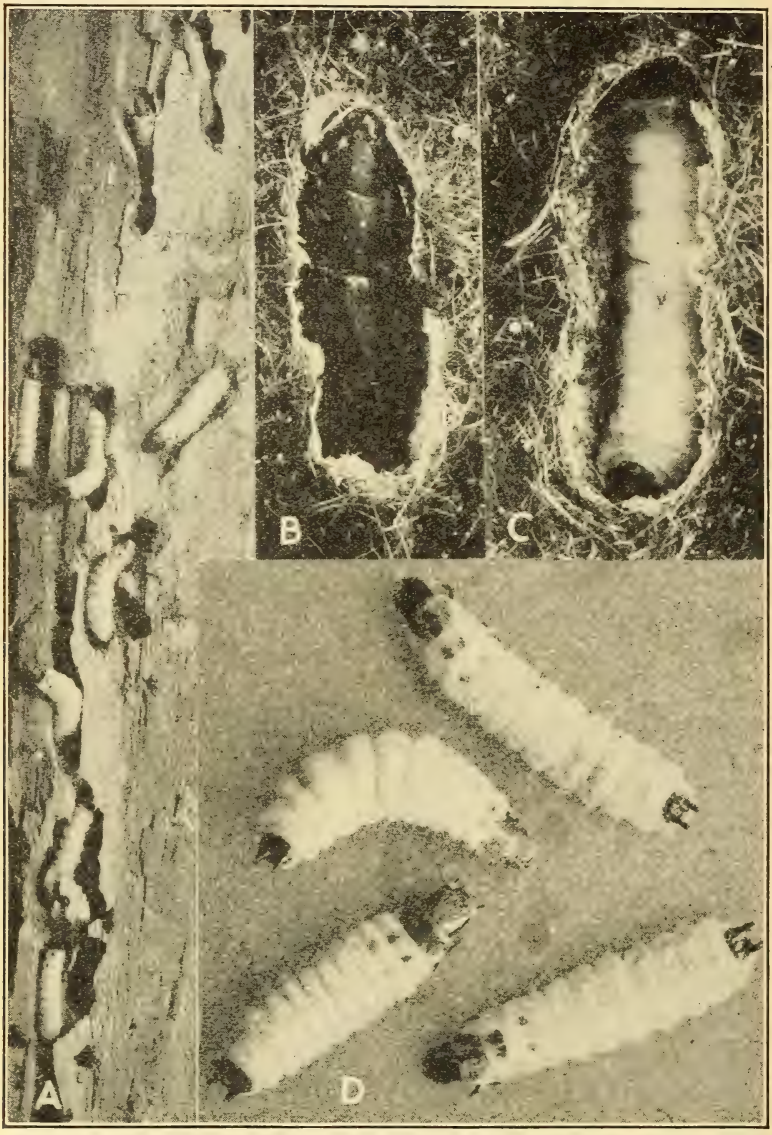

FIG. 9.—Hibernation of the cadelle: A, Sectioned softwood board from granary used for wheat storage, showing numerous larvæ of cadelle using board for protection during winter months; D, cadelle larvæ about to pupate; C, cadelle larvæ hibernating in chamber cut in Wilton rug; B, same as C, only several months later, after larva has transformed to adult

timbers or boards were joined. In warehouses with wooden floors used for the storing of grain and grain products, such as ordinary establishments handling animal feeds, the insects secrete themselves

in large numbers in burrows in the wood itself or between or beneath the boarding.

Since cadelle larvæ and adults may hibernate during the winter months and larvæ may live through a starvation period of from six months to two years, it can easily be appreciated that a warehouse or granary may be cleared of an infested lot of material and thoroughly cleaned in so far as this can be accomplished with broom and whitewash, and yet be so infested with cadelle larvæ and adults that a new supply of grain products, such as cattle feed and cartoned breakfast foods, may be subjected to a truly tremendous onslaught of cadelles as soon as warm weather or transformation permits. In one instance, 800 bushels of wheat, threshed in July and placed in a wooden granary the woodwork of which had been well honeycombed with cadelles, was found so heavily infested with cadelles in September that the kernels appeared to be alive and moving. There was no doubt that the cadelles in the woodwork entered the freshly threshed wheat as soon as it was stored. In the same bin, as soon as cold weather approached, immense numbers of adults and larvæ were observed by the writers to leave the wheat in question and burrow into the surrounding woodwork. Subsequent observation indicated that the farmer sold his wheat before the warm spring weather, but the overwintering cadelles for the most part remained in the wood until the new crop of wheat was placed in the bin the following summer, whereupon they emerged in large numbers and began their attack. Since there is a short summer generation and since the adults are so long-lived and lay so many eggs, the large numbers of cadelle larvæ often found in stored products on the approach of winter weather is easily explained.

As a consequence of its boring habit, the cadelle enters and transforms or hibernates in many substances not attacked as food. An almost endless list of objects thus entered may be expected. The writers found sacks of brown sugar that had been stored on a war ship close by flour, and later removed for storage in a New York warehouse, to contain many lumps in the center of each of which was a hibernating cadelle larva. In another instance larvæ entered rolls of Wilton carpeting and formed pupal chambers by eating away the nap, as shown in Figure 9, B and C. Cadelle larvæ will penetrate an inch of cork stopper in the laboratory if necessary to effect their escape from a bottle. Larvæ will escape from a nest of three pill boxes with the greatest ease. They escape from mailing tubes, and from any cereal cartons known to the writers except those of tin; and paper (fig. 2) and cloth sacks are easily cut. Although escape from a container seems to be the motive for most of the burrowing in food containers in the retail trade, the larvæ can enter ordinary cartoned goods when the cartons are sufficiently close together to allow the larvæ to get a purchase for applying their strength, as, for instance, when the cartons are packed in shipping containers.

LIFE HISTORY AND HABITS

The following data regarding the biology of the cadelle include much that is new. Of special interest are the data dealing with the adult longevity and oviposition and the short and long periods required for larval development.

THE ADULT

A few days before the pupa transforms to the adult (fig. 10), the eyes become dark and the mouth parts and tips of the tarsi begin to color. When first emerged from the pupal skin, the adult is light in color, soft in texture, and very feeble. If exposed it would be unable to protect itself from other carnivorous insects, and therefore it remains within the shelter of its pupal chamber for a week or longer while its tissues are hardening and its color changing to dark reddish brown or black. It then emerges from its cell by eating a characteristically shaped hole (fig. 8, B) through the pupal cell and takes up the struggle for existence.

The beetles prefer darkness to light and usually may be found in dark corners of mills and granaries, between sacks that are stacked close together or in other similar situations.

The food habits of the beetles are very similar to those of the larvæ; but, in addition to eating everything that the larvæ feed on, they will attack and devour the larvæ of almost any insect that they encounter. Beetles were fed in the laboratory with the larvæ of the cheese skipper (*Piophila casei* L.) and larvæ of various flour beetles (Tribolium, etc.). Observations seem to indicate that oviposition is stimulated by the addition of fresh meat to the diet. Beetles do not hesitate to devour larvæ of their own species, or even a newly emerged adult that is prematurely exposed. The beetles are rather pugnacious, and if confined in restricted quarters they will fight until most of them have lost their legs.

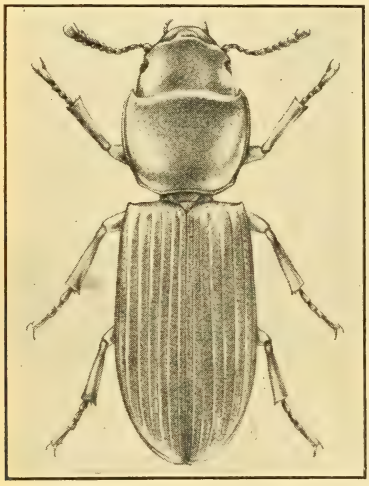

FIG. 10.—The cadelle: Adult beetle. The cadelle is a flattened, black beetle about one-third of an inch long

ADULT LONGEVITY

The cadelle adult is usually long-lived. Kirkup (*17*) records a single specimen that lived for one year and nine months. Slingerland in Herrick (*12*) observed two adults that lived for about one year. As the data of Table 1 indicate, female beetles reared in the laboratory and given food were all very long-lived and many survived for considerably more than a year, the longest record being 668 days.

AGE AT WHICH MATING AND OVIPOSITION BEGIN

During the week or more that the adult cadelle remains sealed within its pupal chamber, there is of course no opportunity for mating. Mating occurs, however, soon after emergence from the pupal chamber and is repeated at irregular intervals throughout life. In summer egg laying begins about two weeks after transformation to the adult, but in the spring months the preoviposition period appears to be considerably longer. In the case of adults emerging in late summer or early fall, no oviposition takes place until the following spring. Data indicating a preoviposition period of from 15 to 210 days are given in Table 1.

TABLE 1.—*Data concerning longevity and oviposition of the female cadelle*

Female No.	Date emerged	First egg laid	Preoviposition period	Last egg laid	Length of oviposition period	Number of eggs laid	Date of death	Length of life
			Days		*Days*			*Days*
1	(1)	July 1, 1922		Sept. 13, 1922	74	530	Sept. 24, 1922	122
2	(1)	do		Oct. 15, 1922	106	1,190	Dec. 2, 1922	191
3	(1)	do		Aug. 28, 1922	58	436	Nov. 28, 1922	187
4	Aug. 7, 1922	Aug. 22, 1922	15	Sept. 8, 1923	382	1,311	Mar. 14, 1924	585
5	do	do	15	Aug. 8, 1923	351	597	Mar. 28, 1924	599
6	do	do	15	Oct. 20, 1923	424	1,087	Dec. 31, 1923	511
7	Aug. 11, 1922	Aug. 27, 1922	16	Aug. 2, 1923	340	990	Nov. 10, 1923	456
8	do	Aug. 26, 1922	15	Sept. 17, 1923	387	931	Feb. 20, 1924	558
9	Aug. 8, 1922	Aug. 28, 1922	20	Aug. 13, 1923	350	493	June 6, 1924	668
10	Aug. 12, 1922	Feb. 9, 1923	181	July 14, 1923	155	1,319	July 23, 1923	345
11	Aug. 19, 1922	Sept. 18, 1922	30	Sept. 12, 1923	359	987	Feb. 23, 1924	553
12	Aug. 20, 1922	Feb. 27, 1923	191	Oct. 15, 1923	230	1,182	Jan. 11, 1924	509
13	Aug. 22, 1922	Mar. 20, 1923	210	Sept. 9, 1923	173	916	Apr. 10, 1924	597
14	Sept. 28, 1922	Mar. 3, 1923	156	Oct. 7, 1923	218	757	Jan. 29, 1924	488

[1] Emerged prior to May 15.

WHERE EGGS ARE LAID

Previously published accounts give little information regarding the egg-laying habits of the cadelle. The adults deposit their eggs loosely in flour or other food materials, or tuck them into crevices of any sort. They prefer to place them in some protected situation, such as beneath insecurely pasted flaps of cartoned goods, in corrugated cardboards, through the mesh of fabric used as containers for flour or grains, and in floor cracks. The eggs are placed side by side in batches containing usually from 10 to 60 each, although as few as four eggs, and as many as 91, have been found in a single batch. The average number of eggs placed in a batch is 25 (see Table 2). In securing eggs, advantage was taken of the female's preference for oviposition in crevices by offering her small pieces of sheet cork fastened together with paper clips and placed on top of the food in the jar in which she was kept. The beetle invariably placed her eggs in batches between the sheets of cork, hence it was a simple matter to change the cork daily and record the eggs laid. The reader should refer to Figure 11 for photographic records of the manner of oviposition in crevices. In ovipositing into flour, through a cloth covering, the eggs are arranged in many planes.

PERIOD OF OVIPOSITION

With the presentation of the data of Table 2, the writers are able to give for the first time authentic information concerning the period of oviposition of the cadelle.

It will be noted that oviposition, in one instance (No. 6), began August 22, 1922, and ended October 20, 1923. This record, extending over a period of almost 14 months, is the longest known. Other recorded periods of approximately a year's duration were from August 22 to September 8 (No. 4), August 22 to August 8 (No. 5), August 27 to August 2 (No. 7), August 26 to September 17 (No. 8), August 28 to August 13 (No. 9), and September 18 to September 12 (No. 11). In these seven instances (see Table 2) no eggs were laid during the period from September 20 to February 7, inclusive; and in four of the seven records, none until March 2; in two instances

egg laying was resumed the second week in February and continued with fair regularity throughout that and the following months.

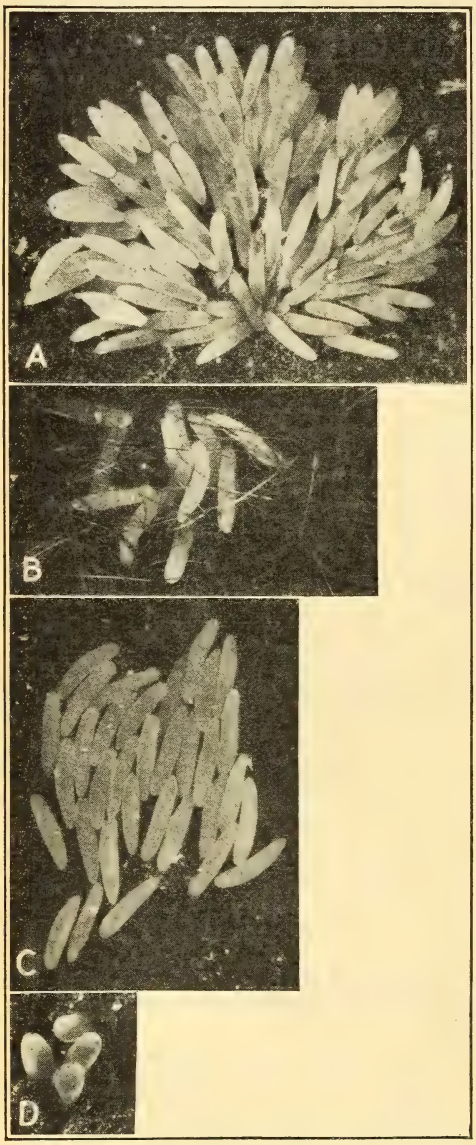

FIG. 11.—Four egg clusters of the cadelle: A, C, Deposited between two flat surfaces; B, in a piece of hat felt; and D, tucked into a hole in a piece of cork

In three instances (Nos. 1, 2, and 3) where females emerging before May 15 began ovipositing on July 1, oviposition ended September 13, October 15, and August 28, respectively, and was followed later in the fall by the death of the adults. Ovipositions that began very early in the season, as during February and March, were completed during that year; four such records extended from February 9 to July 14 (No. 10), February 27 to October 15 (No. 12), March 20 to September 9 (No. 13), and March 3 to October 7 (No. 14).

The oviposition period is, then, quite long, with a minimum of about two months and a maximum of about 14 months. Females emerging during the summer months usually lay a portion of their eggs the same year, cease oviposition with the approach of winter, and begin ovipositing once more during February and March (in warm buildings) or later in ordinary warehouses, and continue laying eggs until exhaustion. Since such adults may continue oviposition until the following October, the resulting oviposition periods are the longest. Other females, emerging during late summer or fall, may not begin ovipositing that year but lay all their eggs during the following calendar year, beginning during February or March in warm structures; such females have short oviposition records in spite of their long

lives. Certain females which emerge very early in the season (as in the case of Nos. 1, 2, and 3 of Table 2, which emerged that spring before May 15, but did not begin oviposition until July 1) complete their oviposition and die before winter, and these have the shortest oviposition periods of all.

TABLE 2.—*Oviposition records of the cadelle*[1]

Date	Number of eggs laid by female No. —													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1922														
July 1	30	13	14											
2			32											
3	50	40												
4	30		18											
6	32	24	13											
8	18													
9	22		18											
10	7													
11	11	8												
13		40												
14	6		20											
15		25												
16	27	20	12											
17	16	32												
18		40	34											
20	31	27												
21		10												
22	11													
23	35	14												
25		32												
27	22	24	24											
28		29												
29	17													
30	12	27	48											
31		46												
Aug. 1		16												
2	9	20												
3	26													
4		21												
6		12	12											
7		19	26											
8		22												
9	17													
11			23											
12	7													
13		12	23											
14	21	8	24											
16		23												
17		12												
18			44											
19		36												
20		34												
21		48												
22	24			7	5	5								
23	11	18		10		11								
24		36			22									
26		59	32	18	7	23		15						
27							12							
28	18		19						9					
29								24						
30				20										
31		3												
Sept. 5		8		45	11									
7	9	49												
8		13												
9				38			9	14						
12		25												
13	11							31						
14		16												
16		43												
17								10						
18		10									14			
19								6						
20		20												

[1] Days on which no eggs were deposited are omitted from the table.

TABLE 2.—*Oviposition records of the cadelle*—Continued

Date	Number of eggs laid by female No. —													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1922														
Oct. 3		39												
5		52												
7		15												
10		23												
15		27												
1923														
Feb. 8											12			
9										7				
10						8								
14										22	18			
16						22								
18											24			
19										25				
21											14			
24											13			
25										58				
27				38						13	14	30		
Mar. 1						32				22				
2								33			22			
3										20				21
4				31				24	32					
6							12			61	18			
7						37	14	6						
9										24				
10												24		
12										16				
13				16				33						
14					54									
16										36				
18										12				
20							25						6	
21						15						34		
22							18			50				4
25						20								28
27									26					
28				30					17	22				
30											23			
31										16		34		
Apr. 2								10					12	
3				33		31				33	31	8		26
5							21							
6				21								56		30
7										31			15	
8						64		28	34					
9				46						18				
11							28					53		32
12								4						
13				40								66		
17						20					25			25
18										16				
19				45								20		
20						10								
21								10						
22					55		31		24	35	30			
24										18				
26								8						
27						10	38		10	28				12
28				38							34	20		
29					12									
30							27	20		30				34
May 1				37	15	40								
2								20			6			
4				44							18		30	
5							35							
6										50				
7												23		
8				64						10	54			
9						46	38	17				5		
11					12									
12							18					12		
13				10	18	24				60				
15							16							
16							54							
17				31	9									
18				40		24	7				16			
19												11		
20							12						14	

TABLE 2.—*Oviposition records of the cadelle*—Continued

Date	Number of eggs laid by female No. —													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1923														
May 21				10				30			20			
22												28		
23				48		46		18					27	
26				48			53			9	15		54	
27								32				8		
28													36	
29				64		40	24				22			
31				38			12	36					58	
June 2				32		38	28	50		15		33		40
3											30	20	40	
4				20									32	
5				42		36						48		
6				44			14					32	24	
7				26			34		12	18		32	34	
8					6									
9						10				28				
10										43			52	
11										68		35		
12				40			22	38					38	
14				36								24		
15					40									
16						32	20	28		52	54	36	30	
18					60							58		
19				40			34	18		56	14		8	
20					10					78				
21												45		
22							18			42	12			
23				10					28			16	16	
24								22						
25				26			30			52	32	35	18	
26						37	18	24	16					
28												16	18	42
29						36	64			54				
30					16						33			
July 1				16								28	14	
2					46									
3						56		38			32			
4														22
5				35	44		14	32	32		32	15	40	
6						45			10				18	8
7					20		38					19	24	
9						32		18			16		34	33
10							12		22	16				
11													26	
12						14	19			25		6		18
14					60					30	32			36
15									39					
16								15						50
17							40				36		64	
18				5				18	56					45
19							18				14			14
20						16							26	
22							11		30		18			
24								32			30			
25									14					12
26						14								
27									16		14			18
29							14	40			23	14	32	
30														72
31							18	25	28			16		
Aug. 1					60						27			
2						18	20		10					
4								10					28	36
6														48
7											24	16		
8					23	14			17					
13									11				30	
20						15								
21											26			15
25						12								
30								16						
31												41		
Sept. 1				12										
3						22					16	34		
7								30						
8				17										
9						10		32				45	18	
12											29			10

TABLE 2.—*Oviposition records of the cadelle*—Continued

Date	Number of eggs laid by female No. —													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1923														
Sept. 17								16						
18												41		
21												10		
25						31								
27												23		
Oct. 3														16
7						15								10
15						48						12		
20						8								
Total	530	1,190	436	1,311	605	1,087	990	931	493	1,319	987	1,182	916	757

FREQUENCY OF OVIPOSITION

The cadelle female does not oviposit with regularity. Eggs may be deposited daily or every other day during the period of greatest egg-laying activity, although intervals of from 10 to 14 days, more or less, when no eggs are laid, frequently occur even during seasons of favorable climatic conditions. In Table 2, containing data on the oviposition of 14 females, there are only six instances in which eggs were laid each day for periods of three or four days. Thus No. 2 deposited 25, 20, 32, and 40 eggs on July 15, 16, 17, and 18, respectively, 27, 46, 16, and 20 on July 30 and 31 and August 1 and 2, respectively, and 36, 34, and 48 eggs on August 19, 20, and 21, respectively; No. 4 deposited 20, 42, 44, and 26 eggs on June 4, 5, 6, and 7, respectively; No. 12 deposited 48, 32, and 32 eggs on June 5, 6, and 7, respectively; and No. 13 deposited 40, 18, and 24 on July 5, 6, and 7, respectively.

Eggs are frequently laid every other day and sometimes every day during the height of oviposition activity. Thus No. 2 deposited 8, 40, 25, 20, 32, 40, 27, 10, 14, 32, 24, 29, 27, 46, 16, 20, 21, 12, 19, and 22 eggs on July 11, 13, 15, 16, 17, 18, 20, 21, 23, 25, 27, 28, 30, and 31, and August 1, 2, 4, 6, 7, and 8, respectively. A more usual record, however, is that of No. 10, which deposited 22, 20, 61, 24, 16, 36, 12, 50, 22, and 16 eggs on March 1, 3, 6, 9, 12, 16, 18, 22, 28, and 31, respectively. Although egg deposition ceases in most instances during October, November, December, and January, one female (No. 2) deposited 39, 52, 15, 23, and 27 eggs on October 3, 5, 7, 10, and 15, respectively, before stopping oviposition for the winter period. A study of the data of Table 2, in conjunction with other records not included, indicates an irregularity in oviposition that can not be predicted.

NUMBER OF EGGS DEPOSITED BY SINGLE FEMALES

Previous investigators have not determined the egg-laying capacity of the cadelle, hence the records given in Table 2 are the first ever published of females of known age and with oviposition records broken by a period of winter inactivity. The junior writer (*3, p. 62–63, nos. 330, 331, 337*), in a preliminary report, gave records Nos. 1 to 3 occurring in Table 2, which subsequently obtained data

indicate to be fairly trustworthy as complete oviposition records for females emerged before May 25 and reaching their egg-laying capacity before the winter following.

The maximum number of eggs deposited by any cadelle under observation is 1,319; the minimum, 436. The 14 females whose records are included in Table 2 laid 530, 1,190, 436, 1,311, 605, 1,087, 990, 931, 493, 1,319, 987, 1,182, 916, and 757 eggs, respectively. The 10 females depositing the largest number of eggs deposited an average of 1,067 eggs; whereas the average for the entire 14 females of Table 2 is about 910 eggs. The number of eggs laid at a time varied from 3 to 78. In one instance, not recorded in Table 2, a female beetle deposited 91 eggs in a single batch.

THE EGG

The incubation period of the egg varies considerably, being influenced chiefly by the prevailing temperatures. The data of Table 3 indicate the length of the egg stage as determined by the writers under laboratory conditions when the mean temperatures ranged from 69.2° to 85° F. It will be noted that during February and March, 1923, when the mean temperatures ranged from 70° to 71° F., the length of the incubation period was from 15 to 17 days. Later in the spring and in the summer (1922), as the daily means rose, the length of the incubation period became shorter until with an average mean of 80°–85° F., it was reduced to a minimum of 7 days. The data of Table 3 cover those portions of the year when the adult cadelle oviposits in the laboratory at Washington, D. C., and indicate a minimum incubation period of 7 days and a maximum of 17 days.

TABLE 3.—*Incubation period of egg of the cadelle*

No.	Date egg laid	Date egg hatched	Length of incubation period	Average mean temperature for incubation period
			Days	° *F.*
1	Apr. 27, 1922	May 7, 1922	10	71.4
2	May 6, 1922	May 15, 1922	9	74.2
3	May 7, 1922	May 16, 1922	9	74.5
4	June 5, 1922	June 12, 1922	7	85
5	June 6, 1922	June 13, 1922	7	84.3
6	June 7, 1922	June 14, 1922	7	83
7	June 16, 1922	June 23, 1922	7	80
8	July 3, 1922	July 10, 1922	7	80.5
9	Aug. 3, 1922	Aug. 11, 1922	8	79
10	Oct. 5, 1922	Oct. 15, 1922	10	74
11	Oct. 7, 1922	Oct. 17, 1922	10	73
12	Feb. 24, 1923	Mar. 13, 1923	17	71
13	Feb. 25, 1923	Mar. 13, 1923	16	71
14	Feb. 27, 1923	Mar. 14, 1923	15	71
15	Mar. 2, 1923	Mar. 17, 1923	15	71
16	Mar. 6, 1923	Mar. 22, 1923	16	70.8
17	Mar. 22, 1923	Apr. 6, 1923	15	70
18	Apr. 2, 1923	Apr. 14, 1923	12	71
19	Apr. 6, 1923	Apr. 20, 1923	14	69.2
20	Apr. 13, 1923	Apr. 27, 1923	14	70.6
21	Apr. 19, 1923	May 2, 1923	13	72
22	May 18, 1923	May 28, 1923	10	76
23	May 23, 1923	June 1, 1923	9	77.4

THE LARVA

The young larva, after effecting its escape through one end of the eggshell, is almost transparent in appearance and is so small that it is scarcely noticeable to the unaided eye. It is sensitive to light and at once attempts to burrow out of sight within whatever food substance is at hand. If no food is present it will conceal itself within or beneath any object that affords shelter.

FOOD OF LARVA

The larva (fig. 9, A, D; fig. 12) is voracious and, with a favorable environment, will grow rapidly. It will feed on an almost endless variety of foodstuffs but does not thrive equally well on them all. It will feed on all grains and their milled products, such as corn, wheat, oats, barley, rice, all kinds of flours, meals, stock feeds, biscuits, and bread. It feeds freely in many kinds of nut meats and seeds and various dried fruits and vegetables. Although developing more rapidly on the germ of the grain, the cadelle feeds also on the harder portions, and frequently, in the case of wheat, so eats the kernel that nothing is left but a thin shell. In feeding upon corn on the cob (fig. 4, C), the larva eats out the softer germ, thus forming a chamber in which it is frequently entirely concealed and from which it eats a longitudinal channel to the outer end and escapes from the kernel by eating a characteristic slitlike opening well illustrated in Figure 4, C.

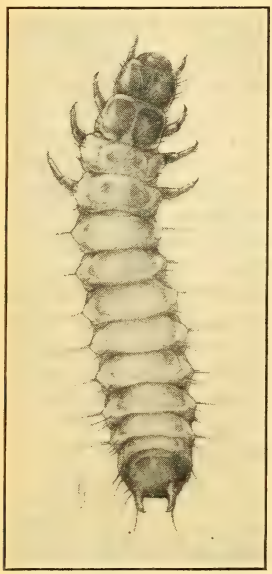

FIG. 12.—The cadelle larva. Commonly found crawling among grain kernels. It may appear glistening white or dull and powdered according to the material in which it is crawling. When full grown it is about three-fourths of an inch long

Effect of diet upon growth of larva.—During the season of 1922 hundreds of cadelle larvæ were reared in the laboratory in individual vials, and several different foods were experimented with. It was found that the type of food used had a marked influence over the rate of growth of the larva. The larvæ were placed in individual vials and kept under identical conditions as regards temperature and moisture. Each was supplied with an abundance of food, the only difference being in the kind of food supplied. The foods used were corn, wheat, rough rice, Graham flour, barley flour, and refined white flour. The larvæ fed upon corn, wheat, and Graham flour grew with great rapidity and completed their growth in approximately the same length of time. These larvæ all hatched during the first week in May and completed their growth in about 69 days. Those fed on barley flour did not grow quite so rapidly but a few of them completed their growth about two weeks after the corn, wheat, and Graham-flour-fed larvæ. Those fed on rough rice grew still more slowly and did not transform until the following summer. The larvæ fed upon the refined white flour developed very slowly, many

of them died after living a few months, none completed their development, and the few that were still alive after 18 months were only about half grown. Certain larvæ lived to be about 2 years old without reaching maturity.[3]

Larva often found in substances upon which it does not feed.—When well grown the larva may migrate from its food in search of a protected place in which to form its pupal chamber and transform to the adult stage. The larva may therefore be found in strange places and foods and cause unnecessary alarm. Thus larvæ may bore into bags of sugar (*30*) and salt, cornstarch, rolls of carpets and rugs, balls of twine, corrugated cardboard, in soft wood, and have even been found in bottles of milk (*28*). Of course their presence in such places is accidental and usually is of no economic importance except as they render such foods unpalatable if their presence is noted. In certain instances the cutting of fibers, etc., by the larvæ in forming their cocoons may seriously affect a commodity.

CARNIVOROUSNESS OF LARVA

Much has been said regarding the carnivorous habits of the cadelle larva, and a survey of the literature relating to this insect would lead one to suspect that the larva kills and devours any other insect larva that it chances to encounter. To determine the truth of the matter a large number of cadelle larvæ were confined separately in small glass vials with a small quantity of flour and a number of larvæ of other flour-infesting insects. At the end of a few weeks the vials were inspected and it was discovered that in almost every case all the larvæ were alive and thriving although the cadelle larva must have been in a more or less close contact with some of the other larvæ most of the time. In a few cases some of the other larvæ were found dead and these probably had been killed by the cadelle larva. Further experiments were conducted by placing several cadelle larvæ together in glass Petri dishes with and without food and with or without other insect larvæ. It was found that the cadelle larvæ upon encountering each other would frequently thrash around and inflict wounds with their mandibles which in time caused death to ensue. In this way in the course of a week or two a good many were killed, but the living larvæ made no attempt to feed upon the dead bodies, and it seems quite likely that the mortality was due mainly to the restricted space rather than to any carnivorous proclivities of the larvæ. The other insect larvæ that were confined with the cadelle larvæ fared much better than the cadelles, possibly because of their smaller size and greater activity; a few were killed but the majority escaped and there was no evidence to show that the cadelle larvae fed upon the remains of the few that were killed. In one instance a cadelle larva was accidently confined in a vial with the larva of the black carpet beetle (*Attagenus piceus* Oliv.) for several months without food. Upon examination both larvæ were found to be alive and uninjured.

LENGTH OF LARVAL STAGE

The length of the larval stage varies considerably. It is influenced by various factors, the more important of which are the abundance

[3] This is true in spite of the fact that tremendous numbers of well grown larvæ have been taken from white flour that has been in storage for some months.

and kind of food, the time of year in which the young larva hatches, and the prevailing temperatures.

The effect of the food supply on the duration of the larval growth has been discussed in a preceding paragraph. It was found that when the larva is reared on certain foods such as corn, wheat, Graham flour, etc., growth is rapid and, other conditions being favorable, the larval stage is short, whereas if the larva is fed upon less nourishing foods, growth is correspondingly slower and the larval stage may be considerably prolonged.

Of several hundred cadelles hatched at different times of the year and supplied with an abundance of suitable food a great many completed their growth and transformed within 3 months, a majority within 7 months, and all within 14 months after hatching. (Table 5.) Of a large group fed upon refined white flour none succeeded in transforming, although certain of them lived to be about 2 years old.

The time of the year when the young larva hatches apparently has some bearing on the duration of the larval stage aside from the influence to be expected from changing climatic conditions. Of the larvæ that hatch in the late spring and early summer months, although rearing conditions may be to all appearances identical, a certain percentage have a short larval life and transform the same year, as indicated by the data of Table 7, whereas the rest have a long larval life and do not transform until the following spring or summer, as indicated by the data of Table 8. The rearing records of the several hundred cadelles mentioned in the preceding paragraph show that all larvæ that hatched in March and April completed their growth and transformed the same year; 90 per cent of those hatching in May transformed that year, 40 per cent of those hatching in June, 10 per cent of those hatching in July, but none of those hatching in August transformed the same year. Table 4 contains the data just mentioned and also gives the minimum, maximum, and average lengths of the larval stage for the larvæ that hatch during the different months of the active breeding season. It is interesting to note at this time that of the specimens reared those having the shortest larval life and those having the longest larval life all hatched in June of the same year and were reared under identical conditions.

TABLE 4.—*Influence of time of hatching upon length of larval stage of the cadelle*

Month in which larva hatched	Number of larvæ	Transforming same year	Length of larval stage		
			Minimum	Maximum	Average
		Per cent	*Days*	*Days*	*Days*
March	25	100	93	138	100
April	15	100	80	104	89
May	51	90	60	376	102
June	59	40	48	414	209
July	47	10	62	346	270
August	26	0	233	318	272

Temperature naturally has a marked effect upon the duration of the larval stage but its effect is often modified or vitiated by the nature of the food and time of hatching of the larva. As a general rule, the larval stage becomes shorter as the seasonal temperature increases. Table 5 contains data showing the variation in the

length of the larval stage of larvæ that hatched at different times of the year. It also gives the average mean temperature for each larval period. It may be noted that the average mean temperature for the minimum larval period of 93 days for the larvæ hatching in March was 73° F., for the minimum larval period of 80 days for the larvæ hatching in April the temperature was 79° F., for the minimum larval period of 60 days for the larvæ hatching in May, 80° F.; for the minimum larval period of 48 days for the larvæ hatching in June, 82° F.; for the minimum larval period of 62 days for the larvæ hatching in July, 80° F.; and for the minimum larval period of 233 days for the larvæ hatching in August and extending over winter months, 71° F.

TABLE 5.—*Duration of larval stage of the cadelle*

No.	Date hatched	Date pupated	Length of larval stage	Average mean temperature for larval period
			Days	*° F.*
1	May 7, 1922	Aug. 4, 1922	89	80
2	do	July 29, 1922	83	80
3	do	Aug. 11, 1922	96	80
4	May 15, 1922	Apr. 22, 1923	342	74
5	do	July 30, 1922	76	80
6	do	July 25, 1922	71	80
7	do	July 14, 1922	60	80
8	do	Apr. 16, 1923	336	74
9	do	May 9, 1923	359	74
10	May 16, 1922	July 28, 1922	73	80
11	do	May 27, 1923	376	73
12	do	July 26, 1922	71	80
13	June 12, 1922	May 9, 1923	331	74
14	do	Aug. 7, 1922	56	81
15	do	do	56	81
16	do	Apr. 6, 1923	298	74
17	June 13, 1922	Aug. 1, 1923	414	74
18	do	Apr. 8, 1923	299	73
19	do	July 12, 1923	394	74
20	do	June 25, 1923	377	74
21	do	June 20, 1923	372	74
22	do	June 3, 1923	355	73
23	do	Apr. 6, 1923	297	73
24	June 14, 1922	Apr. 24, 1923	314	73
25	June 17, 1922	Aug. 7, 1922	51	82
26	do	May 6, 1923	323	73
27	June 20, 1922	June 17, 1923	362	74
28	do	Aug. 7, 1922	48	82
29	June 23, 1922	Apr. 1, 1923	282	73
30	July 10, 1922	June 9, 1923	334	73
31	do	Apr. 30, 1923	294	73
32	do	Apr. 8, 1923	272	73
33	do	Apr. 4 1923	268	73
34	do	Sept. 17, 1922	69	80
35	do	Sept. 10, 1922	62	80
36	do	Sept. 21, 1922	73	80
37	do	June 21, 1923	346	73
38	Aug. 11, 1922	May 3, 1923	265	71
39	do	Apr. 1, 1923	233	71
40	do	June 25, 1923	318	72
41	Aug. 14, 1922	Apr. 30, 1923	259	71
42	Aug. 25, 1922	June 3, 1923	282	71
43	do	May 30, 1923	278	71
44	Mar. 13, 1923	June 19, 1923	98	73
45	Mar. 14, 1923	June 29, 1923	107	74
46	Mar. 17, 1923	June 21, 1923	96	74
47	do	July 11, 1923	116	75
48	do	June 19, 1923	94	73
49	do	Aug. 2, 1923	138	76
50	do	June 18, 1923	93	73
51	Apr. 14, 1923	July 27, 1923	104	78
52	do	July 8, 1923	85	77
53	Apr. 26, 1923	July 19, 1923	84	79
54	Apr. 27, 1923	July 16, 1923	80	79

The shortest larval period observed was 39 days from the date of hatching to assumption of the prepupal state, or 48 days to the date of pupation. This larva hatched on June 20, 1922, and pupated August 7, 1922. It was fed on corn.

The longest larval period observed of those reared on favorable food was 414 days. This larva was also reared on corn.

The phenomenally long larval period, noted first by Kirkup (*17*) in 1812 and more recently by McColloch (*22*) in 1922, was probably due to unfavorable food or environmental conditions. Kirkup recorded the case of a single larva which fed for more than 15 months before transforming, its food apparently consisting only of the almond nut in which it was found; how long it had been feeding before discovery can not be predicted but it might have been several months. McColloch found that larvæ lived from 628 to 1,248 days before transforming, the larvæ being fed wheat, wheat bran, and flour.

NUMBER OF MOLTS

The cadelle larva usually molts either three or four times, although five, six, and seven molts are not unusual when the larval period is long. If for any reason the larval period is prolonged beyond its normal length, many more molts may occur. The writers observed one larva to molt nine times and McColloch observed another to molt no less than eleven times.

Observations show that the larvæ that hatch in the early spring, if supplied with favorable food, molt only three times. Of those that hatch later in the year, about one-half molt three times and the rest four times, even though food supplies and other conditions are apparently identical. Larvæ that winter over, although apparently fully grown, sometimes start feeding again in the spring and may molt once or twice in the spring before transforming. When possible the larva seeks a sheltered place in which to molt; at other times, when breeding in flour, it comes to the surface to molt.

LENGTH OF LARVAL INSTARS

The different larval instars naturally vary considerably in length at different times of the year, but during the summer months they are more or less uniform. Their average lengths in summer are: First instar, about 11 days; second instar, about 11 days; third instar, about 14 days; fourth instar, about 18 days; and fifth instar, when it occurs, about 11 days. A more comprehensive idea of the relative lengths of these instars and the variation in them can be obtained by a study of Tables 7 and 8, which give complete life-history data of a number of individuals.

PUPATION

After attaining its growth the larva becomes restless and wanders about seeking a place of safety in which to undergo the transformations to the pupal and adult forms. It prefers to burrow into a piece of soft wood, hollow out a small chamber, and close up the open end with a cement made from the borings mixed with a larval secretion. It occasionally crawls between two boards and forms its cell between them, especially if the boards are of hard wood (fig 13).

FIG. 13.—Cadelle pupæ in pupal chambers. Wood sectioned to expose pupæ within chambers. Note burrow made by larva in arriving at place chosen for pupation

The walls and floor of almost any wooden bin, granary, or warehouse which has been used as a storage place over a period of years for wheat, corn, or other foodstuffs will show evidence of their bur-

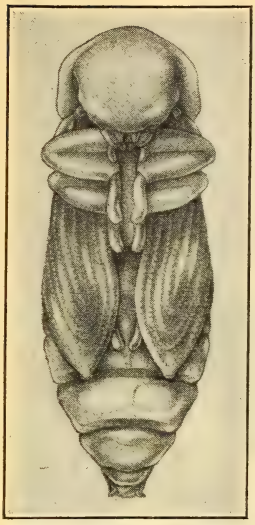

FIG. 14.—The cadelle pupa, much enlarged. The pupa is seldom seen as this stage of the cadelle's life cycle is spent in a cell made in an inaccessible place.

rowing. The damage resulting from this habit has been previously referred to. If nothing better is available, the cadelle larva will form its cell in a hollowed-out kernel of corn, filling the openings with the cement; or it will construct a cell out of pieces of grain cemented together. Finally, if nothing suitable is available, it will transform without forming a pupal cell. Larvæ that hibernate usually construct their pupal cells in the fall but do not transform until spring.

Larvæ that were reared in the laboratory were supplied in most cases with small pieces of cork into which they bored and soon disappeared from sight when ready to transform. After a prepupal stage lasting, in summer, from 7 to 17 days (averaging about 9 days), the pupal form (fig. 14) is assumed.

THE PUPA

The insect remains in the pupal stage from 8 to 25 days, the length of this stage being influenced mainly by the prevailing temperatures. Table 6 contains data on the length of the pupal stage and the relation of temperature to the length of the stage. Apparently the cadelle does not pass the winter months in the pupal stage.

TABLE 6.—*Duration of the pupal stage of the cadelle*

No.	Date pupated	Date adult emerged	Length of pupal period	Average mean temperature for pupal period
	1922	1922	*Days*	° *F.*
1	July 14	July 25	11	82
2	24	Aug. 3	10	82
3	25	7	13	81
4	29	10	12	80
5	Aug. 1	15	14	78
6	19	Sept. 1	13	77
7	26	8	13	79
8	26	9	14	79.5
9	Sept. 27	Oct. 14	17	73
10	10	Sept. 24	14	76
11	17	Oct. 1	14	72
12	18	3	15	72
13	20	6	16	73
	1923	1923		
14	Mar. 27	Apr. 16	20	69
15	28	13	16	73
16	30	22	23	72
17	Apr. 1	25	24	70
18	1	23	22	70
19	6	May 1	25	70.5
20	8	1	23	70
21	8	3	25	70
22	11	5	24	71
23	24	16	22	72
24	27	17	20	73
25	30	19	19	73

TABLE 6.—*Duration of the pupal stage of the cadelle*—Continued

No.	Date pupated	Date adult emerged	Length of pupal period	Average mean temperature for pupal period
	1923	1923	*Days*	° *F.*
26	May 1	May 21	20	73.5
27	6	27	21	74
28	9	28	19	74.5
29	9	27	18	74
30	13	30	17	76
31	15	31	16	77
32	27	June 8	12	83
33	June 3	15	12	81
34	10	23	13	81
35	17	26	9	85
36	21	July 1	10	84
37	25	4	9	83
38	23	4	11	83
39	July 12	21	9	85
40	14	22	8	84

LENGTH OF LIFE CYCLE

It has been assumed by previous writers that there is but one generation of the cadelle each year under favorable conditions. These investigations prove that there are often two generations, and that there may be a partial third generation a year in the vicinity of Washington, D. C., with ample evidence that in a tropical climate three generations may normally occur under favorable food conditions. The shortest developmental period from egg to adult observed by the writers was 67 days, from June 13 to August 19, 1922, when the average mean temperature for the period was 81° F. The adult was a female and oviposited for the first time September 18, 1922, completing a life cycle from egg to egg in 97 days. It is not likely that the cycle is ever much shorter than this in the vicinity of Washington, and usually it is considerably longer. In Table 7 are given data on what are termed by the writers the "short developmental period," egg to adult, completed during one season of activity, as compared with the data in Table 8 covering the much longer developmental period, egg to adult, when the insect overwinters as a larva. It will be noted that when the developmental period from egg to adult is completed during a single season of activity, this period varies from a minimum of 67 days to a maximum of 134 days. With life cycles during which the larva hibernates, the egg-to-adult period lasts from 271 to 410 days. When it is realized that should the insect be accidentally placed in cold storage with its food at temperatures ranging from 40° to 50° F., it will remain inactive for well over a year only to resume activity on the removal of its food to ordinary trade channels, one can easily appreciate that the life cycle is capable of tremendous prolongation. In this connection one should not forget the remarkable larvæ reported by McColloch (*22*) that lived 628 to 1,248 days before transforming.

TABLE 7.—*Short developmental period of the cadelle, egg to adult, completed during one season of activity*

No.	Date egg laid	Date egg hatched	Incubation period	Date of first molt	Length of first larval stage	Date of second molt	Length of second larval stage	Date of third molt	Length of third larval stage	Date of fourth molt	Length of fourth larval stage
	1922	1922	*Days*	1922	*Days*	1922	*Days*	1922	*Days*	1922	*Days*
1	Apr. 27	May 7	10	May 23	16	June 3	11	June 20	17	----------	25
2	---do----	---do----	10	May 20	13	June 4	15	June 25	21	----------	20
3	---do----	---do----	10	May 18	11	---do----	17	June 20	16	July 13	23
4	---do----	---do----	10	May 17	10	June 3	17	June 18	15	July 15	27
5	---do----	---do----	10	---do----	10	June 1	15	June 17	16	July 6	19
6	---do----	---do----	10	May 25	18	June 3	9	June 18	15	July 5	17
7	---do----	---do----	10	May 22	15	---do----	12	June 20	17	----------	25
8	---do----	---do----	10	---do----	15	June 7	16	June 23	16	----------	24
9	May 5	May 15	10	May 28	13	June 6	9	June 21	15	July 20	29
10	---do----	---do----	10	May 29	14	---do----	8	June 19	13	----------	26
11	---do----	---do----	10	---do----	14	June 10	12	June 22	12	----------	27
12	---do----	---do----	10	---do----	14	June 17	19	June 29	12	July 14	15
13	---do----	---do----	10	May 25	10	June 6	12	June 19	13	----------	28
14	May 6	---do----	9	May 27	12	June 10	14	June 21	11	July 6	15
15	---do----	---do----	9	May 28	13	June 6	9	June 20	14	----------	14
16	---do----	---do----	9	May 26	11	June 10	15	June 23	13	July 12	19
17	---do----	---do----	9	---do----	11	---do----	15	---do----	13	July 10	17
18	May 5	---do----	10	---do----	11	---do----	15	June 27	17	July 18	21
19	May 7	May 16	9	May 29	13	June 6	8	June 18	12	July 11	23
20	---do----	---do----	9	May 31	15	June 11	11	June 27	16	----------	20
21	---do----	---do----	9	do----	15	---do----	11	June 25	14	July 11	16
22	June 5	June 12	7	June 24	12	July 4	10	July 15	11	----------	14
23	---do----	---do----	7	June 22	10	July 3	11	July 13	10	----------	15
24	---do----	---do----	7	June 24	12	July 5	11	July 17	12	----------	12
25	---do----	---do----	7	June 22	10	July 3	11	July 13	10	----------	16
26	---do----	---do----	7	June 23	11	---do----	10	July 16	13	----------	13
27	June 6	June 13	7	---do----	10	---do----	10	July 13	10	----------	16
28	---do----	---do----	7	June 25	12	July 5	10	July 16	11	----------	13
29	---do----	---do----	7	---do----	12	July 6	11	July 19	13	----------	10
30	---do----	---do----	7	---do----	12	July 5	10	July 17	12	----------	15
31	June 11	June 17	6	June 26	9	---do----	9	July 18	13	----------	11
32	---do----	---do----	6	---do----	9	July 4	8	July 17	13	----------	12
33	June 13	June 20	7	June 29	9	July 5	6	---do----	12	----------	12
34	July 3	July 10	7	July 20	10	July 31	11	Aug. 16	16	----------	24
35	---do----	---do----	7	---do----	10	Aug. 1	12	---do----	15	----------	13
36	---do----	---do----	7	---do----	10	July 31	11	Aug. 17	17	----------	17
37	---do----	---do----	7	---do----	10	July 28	8	Aug. 13	16	----------	20
38	---do----	---do----	7	---do----	10	July 31	11	Aug. 12	12	----------	23
39	July 4	July 11	7	July 21	10	---do----	10	Aug. 16	16	----------	19
	1923										
40	Feb. 25	Mar. 13	16	Apr. 12	30	May 1	19	May 20	19	----------	18
41	Feb. 27	Mar. 14	15	Apr. 11	28	Apr. 30	19	May 22	22	----------	22
42	---do----	---do----	15	---do----	28	---do----	19	May 20	20	----------	18
43	Mar. 2	Mar. 17	15	Apr. 12	26	May 1	19	May 21	20	----------	17
44	---do----	---do----	15	Apr. 11	25	---do----	20	---do----	20	----------	17
45	---do----	---do----	15	May 5	49	May 20	15	June 10	21	----------	9

No.	Date of formation of prepupa	Length of fifth larval stage	Date of pupation	Length of prepupal stage	Date adult emerged	Length of pupal stage	Length of period from egg to adult	Average mean temperature of period from egg to adult	Food of larvæ
	1922	*Days*	1922	*Days*	1922	*Days*	*Days*	°*F.*	
1	July 15	----------	July 25	10	Aug. 7	13	102	79	Graham flour.
2	---do----	----------	July 24	9	Aug. 6	13	101	79	Do.
3	July 23	10	Aug. 4	12	Aug. 17	13	112	79	Do.
4	July 19	4	July 29	10	Aug. 10	12	105	79	Do.
5	July 15	9	July 26	11	Aug 7	12	102	79	Do.
6	Aug. 3	29	Aug. 11	8	Aug. 24	13	119	79	Corn.
7	July 15	----------	July 25	10	Aug. 7	13	102	79	Do.
8	July 17	----------	July 24	7	Aug. 3	10	98	79	Do.
9	July 28	8	Aug. 4	7	Aug. 17	13	104	79	Do.
10	July 15	----------	July 30	15	Aug. 11	12	98	79	Do.
11	July 19	----------	July 29	10	Aug. 10	12	97	79	Do.
12	July 21	7	July 31	10	Aug. 13	13	100	79	Do.
13	July 17	----------	July 27	10	Aug. 8	12	95	79	Do.
14	July 15	9	---do----	12	---do----	12	94	79	Do.
15	July 4	----------	July 14	10	July 25	11	80	80	Do.
16	July 23	11	Aug. 3	11	Aug. 17	14	103	79	Do.
17	July 19	9	July 29	10	Aug. 10	12	96	79	Do.

TABLE 7.—*Short developmental period of the cadelle, etc.*—Continued

No.	Date of formation of prepupa	Length of fifth larval stage	Date of pupation	Length of prepupal stage	Date adult emerged	Length of pupal stage	Length of period from egg to adult	Average mean temperature of period from egg to adult	Food of larvæ
	1922	*Days*	1922	*Days*	1922	*Days*	*Days*	*°F*	
18	Aug. 10	23	Aug. 26	16	Sept. 8	13	126	79	Barley flour.
19	July 18	7	July 28	10	Aug. 8	11	93	86	Wheat.
20	July 17		July 26	9	Aug. 7	12	92	80	Do.
21	do	6	July 29	12	Aug. 11	13	96	80	Do.
22	July 29		Aug. 7	9	Aug. 20	13	76	81	Corn.
23	July 28		Aug. 5	8	Aug. 19	14	75	81	Do.
24	July 29		Aug. 9	11	Aug. 22	13	78	81	Do.
25	do		Aug. 7	9	Aug. 19	12	75	81	Do.
26	do		do	9	do	12	75	81	Do.
27	do		do	9	Aug. 20	13	75	81	Do.
28	do		do	9	Aug. 19	12	74	81	Do.
29	do		do	9	do	12	74	81	Do.
30	Aug. 1		Aug. 10	9	Aug. 23	13	78	81	Do.
31	July 29		Aug. 7	9	Aug. 20	13	70	81	Do.
32	do		do	9	Aug. 19	12	69	81	Do.
33	do		do	9	do	12	67	81	Do.
34	Sept. 9		Sept. 27	18	Oct. 14	17	103	78	Do.
35	Aug. 29		Sept. 10	12	Sept. 24	14	83	79	Do.
36	Sept. 3		Sept. 17	14	Oct. 1	14	90	78	Do.
37	Sept. 2		Sept. 18	16	Oct. 3	15	92	78	Do.
38	Sept. 4		Sept. 21	17	Oct. 7	16	96	78	Do.
39	do		Sept. 20	16	Oct. 6	16	94	78	Do.
40	June 7		June 19	12	June 27	8	122	74	Graham flour.
41	June 13		June 29	16	July 11	12	134	75	Do.
42	June 7		June 21	14	July 1	10	124	74	Do.
43	do		do	14	June 28	7	118	74	Do.
44	do		June 19	12	June 27	8	117	74	Do.
45	June 19		June 29	10	July 11	12	131	75	Do.

TABLE 8.—*Long developmental period of the cadelle, egg to adult, with insect overwintering as larva*

No.	Date egg laid	Date egg hatched	Incubation period	Date of first molt	Length of first larval stage	Date of second molt	Length of second larval stage	Date of third molt	Length of third larval stage	Date of fourth molt	Length of fourth larval stage
	1922	1922	*Days*	1922	*Days*	1922	*Days*	1922	*Days*	1922	*Days*
1	May 5	May 15	10	June 1	17	June 13	12	July 6	23	July 24	18
2	May 6	do	9	June 12	28	June 29	17	July 15	16	Aug. 3	19
3	May 7	May 16	9	May 31	15	June 10	10	June 25	15	July 13	18
4	June 6	June 13	7	June 27	14	July 8	11	July 19	11	Aug. 7	19
5	do	do	7	June 25	12	July 5	10	July 16	11	Sept. 23	69
6	June 19	June 26	7	July 9	13	July 20	11	Aug. 1	12	Aug. 17	16
7	July 3	July 10	7	July 23	13	Aug. 2	10	Aug. 22	20	Sept. 18	27
										1923	
8	do	do	7	do	13	Aug. 3	11	Sept. 2	30	May 10	250
										1922	
9	do	do	7	July 20	10	July 28	8	Aug. 7	10	Aug. 25	18
10	do	do	7	July 19	9	July 27	8	Aug. 8	12	Sept. 23	46
								1923			
11	do	do	7	July 21	11	Aug. 2	12	Mar. 19	229		
								1922			
12	Aug. 3	Aug. 11	8	Aug. 23	12	Sept. 4	12	Sept. 20	16		
13	do	do	8	Aug. 26	15	Sept. 6	11	do	14		
14	Aug. 7	Aug. 14	7	Aug. 24	10	Sept. 4	11	Sept. 19	15		
										1923	
15	Aug. 18	Aug. 25	7	Sept. 7	13	Sept. 21	14	Oct. 14	23	Mar. 11	148
16	do	do	7	do	13	Sept. 20	13	Oct. 19	29	Mar. 12	144
17	do	do	7	Sept. 6	12	Sept. 22	16	Oct. 10	18	Mar. 14	155
18	do	do	7	Sept. 4	10	Sept. 18	14	Oct. 18	30	Apr. 6	170
19	do	do	7	do	10	Sept. 19	15	Oct. 28	39	Mar. 10	133
20	do	do	7	Sept. 5	11	Sept. 20	15	Oct. 18	28	Apr. 16	180

TABLE 8.—*Long developmental period of the cadelle, etc.*—Continued

No.	Date of fifth molt	Length of fifth larval stage	Date larva entered hibernation	Date pupated	Length of last larval and prepupal stage	Date adult emerged	Length of pupal stage	Length of period egg to adult	Food of larva
	1922	*Days*	1922	1923	*Days*	1923	*Days*	*Days*	
1	Sept. 25	63	Oct. 14	May 9	226	May 27	18	387	Barley flour.
2			Aug. 23	Apr. 22	262	May 16	24	375	Corn.
3	Sept. 18	67	Oct. 23	May 27	251	June 7	11	396	Broken wheat.
	1923								
4	Apr. 20	256	Aug. 23	July 12	83	July 21	9	410	Corn.
5			Oct. 22	Apr. 6	195	Apr. 29	23	327	Do.
6			Aug. 29	Mar. 20	215	Apr. 6	17	291	Do.
7			Oct. 7	Apr. 8	202	May 3	25	304	Do.
8			Sept. 27	June 10	31	June 23	13	355	Do.
9	Mar. 26	213	Sept. 22	May 13	48	May 30	17	331	Do.
10			Sept. 27	Apr. 3	192	Apr. 27	24	298	Do.
11			Aug. 29	June 21	94	July 1	10	363	Do.
12			Oct. 10	Apr. 8	200	May 1	23	271	Do.
13			Oct. 12	May 8	230	May 27	19	297	Do.
14			Oct. 19	Apr. 27	220	May 17	20	283	Graham flour.
15			Oct. 27	May 30	80	June 10	11	296	Corn.
16			Oct. 25	June 5	85	June 15	10	301	Do.
17			do	June 8	86	June 22	14	308	Graham flour.
18	June 1	56	Oct. 29	June 21	20	July 1	10	317	Do.
19	Mar. 30	20	Nov. 2	June 3	65	June 15	12	301	Do.
20	June 10	55	Oct. 22	June 29	19	July 12	13	328	Do.

SEASONAL HISTORY

The cadelle passes the winter months in the adult or larval stage. The data of Tables 7 and 8 indicate that the time spent by the insect in its egg and pupal stages is fairly short, but great variations may be expected during the larval stage, which may be as short as 48 days or, according to McColloch (*22*), as long as 1,248 days. Furthermore, the adult itself has been known to live almost 22 months and may lay eggs over a period of more than one year (Table 2). Taking these facts into consideration, together with the influence of the time of hatching upon length of larval life (Table 4) the reader can appreciate that the generations become hopelessly confused. In warehouses and granaries the adults overwintering have their numbers greatly augmented during late spring and early summer by the newly emerged adults developing from the overwintering larvæ. It therefore happens that at this season of the year the adults are especially abundant in climates having a cold winter. The overwintering adults begin ovipositing early in the spring (often as early as February in warm buildings) and continue oviposition throughout the summer. Eggs laid during early spring hatch and develop through to adults by the end of June or early July. These midsummer adults lay eggs the larvæ from which usually winter over in all degrees of maturity; many become full grown by fall, and a few transform to the adult at that time. The larvæ that winter over transform in the spring and the emerging beetles lay eggs all through the summer and hibernate during the following winter. In subtropical and tropical climates it seems probable that development is more or less continuous and that there is much overlapping of generations.

TECHNICAL DESCRIPTION

THE BEETLE

Elongate oblong, subdepressed. Shining, dark reddish brown or piceous above; under surface, antennæ, and legs dark reddish brown. Thorax slightly wider than long, widely emarginate at apex, narrowed behind the middle, surface finely and evenly punctate. Elytra twice as long as wide, with base distinctly separated from that of thorax, sides nearly parallel, tips rounded; surface striate, intervals with two rows of fine punctures. Length 6.5 to 10 mm.

The original description of Linné (*20*) follows.

"T. niger subtus piceus, thoracis marginibus antice posticeque dente angulatis. Similis praecedenti, sed quintuplo minor, supra totus niger, subtus, pedibus antennisque, piceus. Elytra striata. Thoracis margo antice dente utrinque prominulo, & postice dente obsoleto."

THE EGG

Slender, elongate, spindle shaped, often somewhat curved; milky white in color, opaque. Length 1.15 to 1.5 mm.; width 0.25 to 0.34 mm.

THE LARVA

FIRST STAGE

The young larva upon hatching measures 1.5 to 1.6 mm. in length and 0.3 mm. in width. It is slender, elongate, and flattened in form; white, almost transparent, in color with eyes and mouth parts darker. Body provided with a few long, stiff hairs. A little later the head capsule, thoracic and anal shields, and cerci turn to a light brown; still later the thoracic and anal shields become nearly black.

Width of larval head 0.23 to 0.28 mm., width of cerci about 0.11 mm.

SECOND STAGE

The second-stage larva is very similar in appearance to that of the first stage but larger and with the thoracic and anal shields darker in color. Length from 3 to 4.6 mm.; width from 0.54 to 0.9 mm.; greatest width of head 0.35 to 0.43 mm.; width of cerci 0.22 to 0.26 mm.

THIRD STAGE

Similar to preceding stage but larger. Length of body 5 to 8 mm.; width of body 1 to 1.5 mm.; greatest width of head 0.55 to 0.80 mm.; width of cerci 0.35 to 0.54 mm.

FOURTH STAGE

Similar to preceding stage but larger. Length of body 7 to 14 mm.; greatest width of body 1 to 2.5 mm.; greatest width of head 0.9 to 1.3 mm.; width of cerci 0.60 to 0.88 mm.

FIFTH STAGE

Mature larva (fig. 15, E) muddy white, elongate, flattened, sides nearly parallel, widest at third to seventh abdominal segments. Maximum length 19 mm., maximum width 3.5 mm. Thoracic segments each with a pair of five-jointed legs. Body soft-skinned. Prothorax with a large chitinized shield composed of two plates separated in the middle by a narrow suture that widens triangularly posteriorly, mesothoracic and metathoracic segments each with a pair of small, chitinized, dorsal plates. In each plate of the mesothorax and metathorax there is a peculiar, small, light spot, probably of glandular nature. Mesothoracic and metathoracic segments and abdominal segments 1 to 8 each with a small, fleshy papilla on alar areas. Abdominal segments 1 to 8 each with a pair of dorsal ampullæ. Body moderately hairy. Nine abdominal segments visible, ninth dorsally carrying a chitinous plate terminating in a pair of heavily chitinized cerci (pseudocerci).

Head (fig. 15, G, H) free, porrect, flattened, quadrate, about as wide as long, occipital foramen posterior and nearly vertical. Frons (fig. 15, G, *f*)

distinctly limited, large, triangular, extending to posterior margin of cranium, provided with four setæ on each side. Clypeus (fig. 15, G, *c*) distinct, broadly

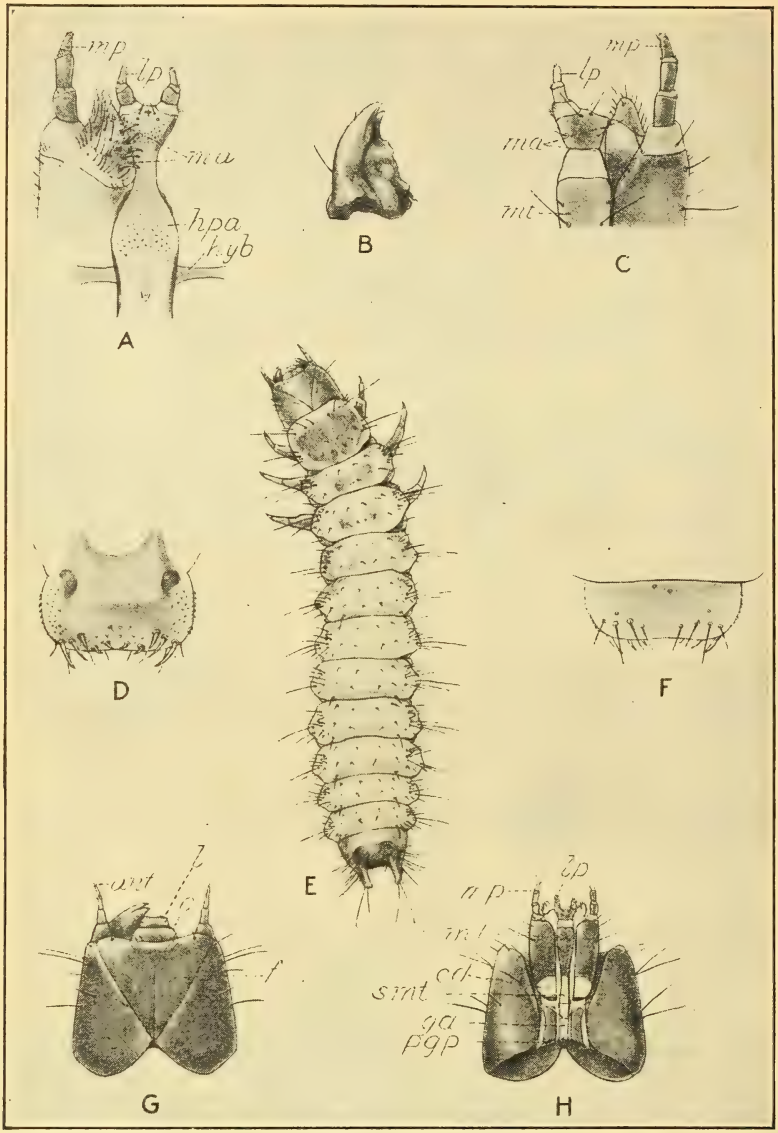

FIG. 15.—Details of fifth-stage larva of the cadelle: A, ventral mouth parts, dorsal view; B, mandible; C, ventral mouth parts, lateral view; D, under side of labrum; E, larva; F, upper side of labrum; G, head capsule, dorsal view; H, head capsule, ventral view. Explanation of abbreviations: *ant*, Antenna; *cd*, cardo; *f*, frons; *ga*, gular area; *hpa*, hypopharyngeal area; *hyb*, hypopharyngeal bracon; *l*, labrum; *lp*, labial palpus; *ma*, maxillary mala; *mp*, maxillary palpus; *mt*, mentum; *pgp*, paragular plates; *sm*, submentum

transverse, about twice as wide as long, not chitinized, leathery, posterior margin with two setæ on each side. Labrum (fig. 15, F; G, *l*) subquadrate, considerably broader than long, lateral margins curved and provided with

minute spines, dorsal surface with four setæ on each side, and with two pairs of sensory spots.

No epicranial suture, epicranial halves separated by gular area, the ventral epicranial margin from mandibular articulation of mandible to cardo slightly concave and somewhat larger than rest of epicranial margin. Gula composed of a longitudinal, membranous gular area (fig. 15, H, *ga*) between a pair of paragular plates (fig. 15, H, *pgp*) which probably are separated from the posterior epicranial margin. The gular area bears a pair of large setæ. Epicranial setæ about six in series along lateral margin of cranium, one near frontal suture on disk of epicranium, one opposite to this near lateral margin, and four small setæ near occiput; one seta on ventral surface near base of antennæ, three small and one large setæ along anterior ventral epicranial margin, and one near lateral margin of cranium. Ocelli five, near base of antennæ, an anterior group of three and posterior group of two.

Antennæ (fig. 15, G, *ant*) well developed, three-jointed, semiretractile, basal membrane large and semiglobular. Basal joint slightly broader and shorter than second joint which bears a small, fleshy, supplementary appendage and several small setæ at distal end. Distal joint slender and bearing one long and two short terminal setæ.

Mandibles (fig. 15, B) subtriangular, large, powerful, fitted for biting, bifid at tip, no molar part, a heavy spinelike process split up like a brush on inner margin near base, with two setæ dorsally and near exterior margin. Ventral mouth parts (fig. 15, C) retracted, no maxillary articulating area. Cardo (fig. 15, H, *cd*) small, with posterior chitinization transversely placed at base of the equally well chitinized stipes. Stipes almost as long as frons, elongate, subrectangular, about three times as long as wide and much larger than cardo, connected with mentum along its entire inner margin.

Maxillary mala (fig. 15, A, C, *ma*) single, flattened, composed of two not joint-like, triangular pieces one above the other, the dividing line clearly indicated on ventral side, indistinct toward the buccal cavity; tip obtuse. On anterior margin just outside line which separates proximal and distal halves a stout, short, and pointed seta. Ventral surface of terminal piece bearing one large seta. Buccal surface of mala profusely covered with setæ, on proximal half about seven very large, hooklike, and obtuse setæ that look and work like a rake.

Maxillary palp (fig. 15, A, C, H, *mp*) three-jointed, carried by a membranous, subannular palpiger maxillæ bearing two setæ on ventral surface and dorsally a tuft of four hairs. Basal and second joints of maxillary palp with a group of minute hairs at tip, second and distal joints each with a seta. Submentum (fig. 15, H, *sm*) between cardines, entirely membranous, anteriorly sharply set off by chitinous mentum, posteriorly by a suture separated from gula. Mentum (fig. 15, C, H, *mt*) chitinized, elongate, subrectangular, bearing on its anterior half two pairs of setæ, one smaller pair in front of the other large pair. Stipes labii much smaller than mentum and free, carrying two pairs of setæ; no separately chitinized palpiger labii; labial palp (fig. 15, A, C, H, *lp*) two-jointed, basal joint with a tuft of hairs at tip. Ligula not developed, floor of buccal cavity soft skinned without any hypopharyngeal chitinization or paragnathal structures but both areas covered with minute asperities. Hypopharyngeal bracon (fig. 15, A, *hyb*) present, hypopharyngeal area (fig. 15, A, *hpa*) with two or three minute chitinized specks.

Epipharynx (fig. 15, D) carrying a pair of chitinized epipharyngeal plates fused in the middle. In front of these there are a pair of minute setæ, a group of six asperities, and two sensory spots. Along the distal margin of the epipharynx are five thickened setæ on each side.

Thorax: Dorsal areas undifferentiated. Prothoracic tergal region almost completely covered by tergal shield. Prothoracic tergal shield with seven pairs of small setæ and one pair of large setæ approximately arranged in three transverse rows. Each lateral margin outside tergal shield bearing six large and three small setæ. The preepipleurum is small, the postepipleurum well developed. Hypopleurum with four setæ and well developed prephypopleural chitinization. Presternal area marked by a pair of rounded, subtriangular plates each with two setæ. Sternum large, composed of preeusternum and eusternum, medianly covered with a large, heart-shaped, chitinous sternal plate. This plate is pointed anteriorly and has a large triangular indentation posteriorly, giving to it the heart-shaped appearance. The sternum carries several large setæ. Poststernellum present and bearing a small, chitinous, subtriangular shield.

Mesothorax and metathorax subequal, each with two transverse rows of six small setæ on tergum and each tergal margin with about nine setæ. Preepipleurum and postepipleurum well developed, preepipleurum of mesothorax bearing a large spiracle, hypopleurum with prehypopleural and posthypopleural chitinizations. Presternum, a larger sternum, a faintly indicated sternellum, and a well developed poststernellum present. Presternum with three setæ on each side, sternum with four parts of setæ and with a faintly indicated sternal plate. Sternal plate of mesothorax subrectangular and about twice as long as that of the metathorax which is quadrate.

Legs five-jointed, chitinized, tarsus and claw fused, tarsus with one seta, other joints each with several setæ.

Abdominal segments dorsally divided into prescutum, scutum, scutellum, and postscutellum. Prescutum with six small setæ. Scutum with a pair of setæ. Alar area large, bearing a bifore spiracle, a small fleshy papilla, and one long, two smaller, and several minute setæ. Epipleural lobe bearing two long, three smaller, and several minute setæ. Hypopleural lobe bearing one long and three small setæ. Coxal lobe bearing five setæ. Sternum large, with two pairs of setæ; sternellum without setæ.

THE PUPA

Pupa uniformly creamy white in color; length from 7 to 10.5 mm., width from 2.5 to 3.5 mm.

Head subquadrate, provided with about 12 pairs of setæ; clypeus with two pairs of setæ and labrum with three pairs.

Prothorax subquadrate, provided with two pairs of anteromarginal, eight pairs of lateromarginal, two pairs of posteromarginal, and usually three pairs of dorsal setæ.

Mesonotum and metanotum usually each provided with two or three pairs of minute, dorsal setæ.

Abdomen with nine distinct dorsal tergites, the ninth being very much reduced and terminating with a pair of short, chitinized, pleural spines. Ventrally the ninth segment bears a pair of prominent fleshy processes. The tenth abdominal segment is small and ventral.

Median area of abdominal tergites 1 to 8 each provided with a pair of setæ, lateral area of each tergite with a pair of setæ, and pleural areas with a pair of long setæ and several minute setæ.

Tips of wing pads usually attaining the fifth abdominal segment; tips of metathoracic tarsi extending to tips of wing pads.

RESISTANCE TO STARVATION

The adults of the cadelle are fairly resistant to starvation even under normal conditions and particularly so when kept at a moderately low temperature. Adults kept in a warm room, with an average mean temperature of about 68° F., survived without food for 52 days. Others kept without food in a refrigerator, with a temperature ranging from 40° to 50° F., survived for a period of 184 days.

The larvæ are very resistant to starvation, much more so than the adults. Of a small lot of larvæ kept without food at room temperature, half of them survived for 4 months, several for 9 months, and one for 10 months. Another lot of larvæ were placed without food in a refrigerator with a temperature ranging from 40° to 50° F.; 10 per cent of these were still alive after 24 months of starvation, but succumbed soon thereafter.

With such powers of resistance to starvation it is easy to see how the cadelle is able to exist over the sometimes considerable periods that the grain bins are empty.

RESISTANCE TO LOW TEMPERATURES

The eggs and pupæ of the cadelle are rather easily killed by low temperatures and these two stages are never found during the win-

ter in the vicinity of Washington, D. C. The larvæ and adults, on the other hand, are very resistant to low temperatures and, protected as they normally are in granaries and storehouses, are able to survive very cold weather. Both larvæ and adults have survived exposure to a temperature of from 15° to 20° F. for a period of several weeks, and will even withstand a temperature of 0° F. for several hours without apparent injury.

CONTROL MEASURES

Cleanliness in the storehouse and granary is one of the most important factors in control. The habit of the larvæ of burrowing into wooden floors, partitions, and walls of bins, storehouses, and ships, accounts for much of the loss occasioned by fresh supplies becoming infested when placed in storage space formerly occupied by infested material. The substitution of concrete for wood whenever possible is one of the best means of preventing the rapid infestation of fresh supplies. On farms where grain bins are usually constructed of wood, hardwood should be used in preference to soft wood, and the construction made as tight as possible. Bins should be inspected annually and any badly burrowed woodwork removed.

The cadelle in all stages can be killed by fumigation with carbon disulphide, from 6 to 8 pounds per thousand cubic feet of bin space being used where bins are tight. In loosely constructed bins even 20 pounds per thousand cubic feet of space might not kill all cadelles in the grain and woodwork. Carbon tetrachloride, alone or in combination with ethyl acetate, has the advantage over carbon disulphide in that its vapor is nonexplosive and noninflammable, but it has the disadvantage of being about one-half to one-third as effective and must therefore be used in greater dosages.

Hydrocyanic-acid gas is effective in killing all stages of the cadelle. It has the disadvantage, however, of not penetrating bulks of grain and flour sufficiently to reach all cadelles. For this reason the cadelle, along with other beetles found in flour mills, can be better killed by the use of heat, as shown by Dean (*7*). Since the cadelle is nearly always associated with other common grain pests, any treatment applied for the control of grain pests in general will be effective against the cadelle.

SUMMARY

The cadelle, *Tenebroides mauritanicus* L., is a very common and destructive cosmopolitan pest of grains and grain products and was first described in 1758. It is usually associated in its attack upon food products with other grain pests. In the case of cartoned goods, such as breakfast foods, the economic importance of the cadelle is much enhanced by the holes it bores in the cartons, thus giving other and smaller pests avenues of attack upon foods that otherwise might remain immune from infestation. The cadelle prefers darkness and secretes itself in both larval and adult stages beneath any object or between sacks of flour or other containers of its food. It therefore is less often seen by the casual observer than other grain pests, even when rather abundant. Both adult and larva are restless feeders and consequently move about feeding here and there, preferring the

germ of the kernel and damaging many more seeds than they can consume. The habit of the larva of crawling into any substance in search of a protected place in which to hibernate or pupate results in the presence of the cadelle in many supplies upon which it does not feed. Since the larva and the adult may bore into wood for hibernation or transformation, the woodwork of granaries and the dunnage of grain ships may harbor thousands of cadelles, which can remain in hiding for months and be ready to swarm out to attack the next consignment of a food commodity that may be stored near them.

The adult cadelle is both predacious and granivorous and appears to produce more eggs if given animal food. Many adults live to be over a year old; one has been known to live almost 22 months. The length of the preoviposition period depends upon the time of year the adult emerges. Observations show that it may be as short as 15 days and as long as 210 days.

The eggs are laid loosely in flour or other food materials, or are tucked into crevices of any sort which offer protection. They may be laid daily or every other day, or more often at irregular intervals with 10 to 14 days or longer frequently intervening. The longest egg-laying period known covered almost 14 months, the first egg having been laid in August of one year and the last in October of the following year. Oviposition periods extending over one year are common, but such records are usually made by females that hibernate during the winter. Adults emerging early in the spring may complete their oviposition before winter. The largest number of eggs deposited by a single female was found to be 1,319; the minimum, 436.

The incubation period was found to range from a minimum of 7 days, when the mean temperature was 80° to 85° F., to a maximum of 15 to 17 days, when the mean temperature for the period was 70° to 71° F.

The larva is not considered to be predacious. Larvæ grow best when fed upon corn, wheat, and graham flour, when they may complete their growth in about 69 days. Those fed on rice grow more slowly. Those fed upon refined white flour develop very slowly. When given the most suitable food and normal surroundings, a great many larvæ complete their development and transform to pupæ within 3 months, a majority of them within 7 months, and all within 14 months. All larvæ hatching in March and April at Washington completed their growth and transformed the same year; 90 per cent of those hatching in May transformed that year, 40 per cent of those hatching in June, 10 per cent of those hatching in July, and none of those hatching during August or later transformed the same year. Reared larvæ having the shortest larval life and those having the longest larval life all hatched in June of the same year and were reared under identical conditions. Under less favorable conditions a larva has required as long as 1,248 days for development, but such long developmental periods are abnormal.

When about to transform, the larvæ form pupal chambers, usually by burrowing into some substance like wood. Once the chamber is sufficiently large it is sealed with borings mixed with a larval secretion. After a prepupal stage averaging about 9 days, the pupal form is assumed. The pupal stage lasts from 8 to 25

days. Apparently the cadelle does not pass the winter months in the pupal stage.

The shortest developmental period from egg to adult observed by the writers was 67 days, when the average mean temperature for the period was 81° F. The adult was a female and oviposited for the first time September 18, completing a cycle from egg to egg in 97 days. It is not likely that the cycle is ever much shorter in the vicinity of Washington, and is usually considerably longer. When the development from egg to adult is completed during a single season of activity the length of the cycle may be from 67 to 134 days. With life cycles during which the larva hibernates, the egg-to-adult period may last from 271 to 410 days.

The cadelle passes the winter months in the adult or larval stage. In warehouses and granaries the adults overwintering have their numbers greatly augmented during late spring and early summer by the newly emerged adults developing from the overwintering larvæ. Adults are, therefore, especially abundant during late spring and early summer in climates having a cold winter. Since overwintering adults begin ovipositing in spring, often as early as February in warm buildings, and continue to oviposit throughout the summer, and since the eggs laid during early spring hatch and develop by the end of June or early July, to adults that in turn lay eggs, the larvæ from which usually winter over in all degrees of maturity (although certain ones may produce adults by fall), the generations become thoroughly confused. In tropical and subtropical climates it seems probable that development is more or less continuous and that there is much overlapping of generations.

Cadelle adults at about 68° F. may withstand starvation as long as 52 days, or for 184 days at 40° to 50° F. Larvæ are more resistant and have survived starvation in warm rooms for 10 months. Certain other larvæ held at 40° to 50° F. without food were still alive after 24 months, but succumbed shortly thereafter.

The eggs and pupæ are easily killed by low temperatures and neither stage has been observed during the winter at Washington, D. C. Larvæ and adults are very resistant; both have survived exposure for several weeks to 15° to 20° F. and will withstand a temperature of 0° F. for several hours without apparent injury.

Among the control measures are cleanliness, fumigation, and the use of heat.

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